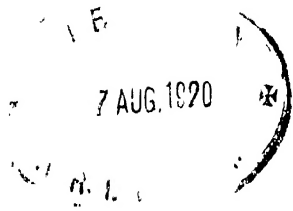


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MEMOIRS
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THE GEOLOGICAL SURVEY OF INDIA

VOLUME XLVII, PART 1.

THE MINES AND MINERAL RESOURCES OF YUNNAN, WITH
SHORT ACCOUNTS OF ITS AGRICULTURAL PRODUCTS
AND TRADE. BY J. COGGIN BROWN, O.B.E., M.I.M.E.,
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ABBREVIATIONS.

In the following list the abbreviations which have been used to denote the works of various authorities referred to in this report are given. The titles of the works are to be found on pages 49—52.

D.	Davies
De.	Deprat
Du.	Duclos
G.	Garnier
La.	Lantenois
Le.	Leclère
R.	Rocher

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PART I.

INTRODUCTION.

Yunnan is the most south-westerly of the provinces of China. It has an area of about 150,000 square miles and a population of approximately 11 millions, of whom roughly one-third are Chinese. "In the plains the population is mainly Chinese, but not entirely so, for in the cold plateaus of the north-west are found Tibetans, while many of the low-lying plains of the south are inhabited by Shans. Moreover in the centre of the province some of the plains are peopled by Ming-chias, while an admixture of Lolos is occasionally found. In the hills things are different. Here, as in the plains, one also finds the Chinese, and there is no large tract of country without Chinese villages in it. But living among them and forming the bulk of the hill population are numerous other tribes, each with its own language and its own customs. In the north-west corner are Tibetans, and the Semi-Tibetan Mo-so tribe. On the Burmese border are Kachins and Palaungs; also in the west of the province, but extending further into the interior, are the Li-sos; everywhere throughout Yunnan are the Lo-los, a fine race and more numerous than any other hill tribe. Equally widely distri-

buted are the Miaos, but they are only found in small and scattered communities. In the south-west, between the Salween and the Mekong are the La-hus, who with their cross-bows and poisoned arrows proved formidable foes to the Chinese troops a few years ago. Near them live the Was, many of whom are still unconquered and still carry on their head-hunting raids. Their relatives, the somewhat more civilized Las, occupy much of the country near the southern part of the Burma-Yunnan frontier. In the south of Yunnan are the P'u-mans; and further east are the Wo-nis and many other tribes speaking Lo-lo dialects." (D, pp. 307-308.)

In addition to these, mention must be made of the various Shan clans which are distributed throughout the valleys and plains but attain their maximum development in the western parts of Yunnan.

On the west, Yunnan is bounded by Burma, Assam and Tibet; on the north by the province of Ssü-ch'uan; on the east by the provinces of Kuei-chou and Kuang-hsi and on the south by Tongking. The western frontier of the province is naturally the most important one from the Indian point of view:—At a common point on the Mekong river in east longitude $101^{\circ} 9'$, and north latitude $21^{\circ} 47'$, the three Empires of British India, China and French Indo-China meet. Northwards from this point the frontier line between Burma and China stretches, in an irregular direction, for some 900 miles till the confines of Tibet are reached. As far as latitude $26^{\circ} 16'$ the boundary between the two countries has been more or less demarcated, but beyond this point a little known region inhabited by wild and savage tribes is passed through. The frontier line through this wild tract remains undefined and uncertain, following generally the line of the watershed of the Irrawaddy and Salween rivers.

With the exception of the great journey of Marco Polo, Yunnan was not visited by Europeans until comparatively recent times and but little was previously known about its geography or resources. From the official Chinese point of view there appears to have been a tendency to regard the province as a mere outpost of the Empire, but this view was finally disposed of by the Mahomedan rebellion which raged for thirty years and was only quelled in 1873 by the fall of Ta-li Fu.

Apart from its size, population and the political importance of its frontiers, marching as they do for hundreds of miles with both

British and French possessions in Asia; Yunnan forms the connecting link between Burma and the valley of the Yangtze. If India and China are ever to be connected by a railway, the line must pass through Yunnan. The province is not a poor country and although the volume of its external trade is not large, this is more a result of its inaccessibility, mountainous surface and the miserable condition of its internal communications. It produces a great variety of animal and vegetable products and its mineral industry only needs transport facilities and the application of modern knowledge to make it of first-rate importance.

I was deputed to Yunnan in November 1907. In June 1908 I returned to Calcutta and in December of the same year I commenced my second expedition, which lasted until May 1910. My journeys in the province totalled some thousands of miles, embraced the greater part of the country, excluding the eastern portions and Yunnanese Tibet, and often extended into new or comparatively unknown areas.

In this final report I shall describe the mines and mineral resources as I found them and add such accounts as have been published by other workers. I shall also give the conclusions I have arrived at regarding the future development of the mineral industry. As this depends to a great extent on the transportation problem, the subject of existing and proposed railways must be mentioned. A few notes on non-mineral industries and trade generally will be added, for although these may appear out of place in a technical report of this kind, such information is difficult to obtain elsewhere, and may be of interest to the reader desirous of increasing his knowledge of an important though little known land.

GENERAL GEOGRAPHY.

Western Yunnan, which may be regarded as that portion of the province situated between the Burma frontier and the Mekong, is occupied by the north-and south-running ranges which separate the valleys of the upper waters of the Irrawaddy, Salween, Mekong and Upper Yangtze. In the extreme north-western corner of Yunnan the tops of the ranges attain heights of 15,000 to 20,000 feet above the sea, and the lowest river valleys lie at about 7,000 feet. Further south, in this section, the heights as a rule gradually decrease, and elevations of 5,000 to 7,000 feet prevail in the Mekong

ranges, the river itself being nearer 2,000 feet. The ranges between the Irrawaddy river and the frontier are held to belong to the Himalayan system as distinct from the Mekong chains.

The parallel courses of the Salween, Mekong and Yangtze, flowing to the south-south-east through Yunnanese Tibet form one of the most remarkable geographical features of the earth's surface. "Each of these rivers drains a large area of Eastern Tibet and on the surface of the plateau they flow at considerable distances from one another. But during their descent they bend to the east-south-east, and assume absolutely parallel courses, the Mekong in the centre being 28 miles from the Yangtze and 20 miles from the Salween" (Burrard and Hayden : *The Geography and Geology of the Himalaya Mountains and Tibet*, p. 127). The parallel arrangement of their courses extends across more than 2 degrees of latitude. The direction of their flow is along well-known tectonic lines, and the profound depths of their cañons is due to late Tertiary or Subrecent uplifts on a grand scale, evidences of which are found throughout the province.

Central Yunnan, extending say from the Mekong valley to the region of the lakes, has been referred to by most writers as a plateau. It is difficult to understand how such a misconception has arisen as this portion is occupied by the western limb and central portion of the Yunnanese arc. Between the Mekong and the Red River the direction of the mountain ranges is north-west and south-east, between the Red River and the lakes a rapid change of direction takes place to approximately east and west, while further on in north-eastern Yunnan high mountain chains stretch far to the north-north-east and form the eastern limb of the Yunnanese arc. The central portion of the arc is thus narrow and compressed; it does not extend much below lat. $23^{\circ} 30'$, and the mountain ranges of the southern part of central Yunnan below this line belong to the Indo-Chinese system.

A little to the south of the 27th parallel and close to the 100th meridian, the Yangtze abruptly changes its course which has up to this point followed the same direction as those of the Mekong and Salween, and after making its well-known bend commences to flow to the east. No satisfactory reason was apparent for this until Deprat pointed out how it depends on the direction of the main lines of folding as apparent in the mountain ranges. "If the Salween, Mekong and Upper Yangtze flow in parallel directions

in their upper valleys, it is because the Mekong ranges and the western branch of the Yunnanese arc are parallel also, but when the Yunnanese ranges curve towards the south, the upper Yangtze leaves its sister rivers, which continue in a southerly direction, and accommodates itself with the folds of the Yunnanese ranges, later it turns towards the north-east with their eastern branches." (De., p. 303).

The ranges of central Yunnan thus form a compressed arc turned towards the south. The Ta-liang-shan ranges which form the independent Lolo country in Ssü-ch'uan occupy part of the concavity of the arc. They themselves form the extremity of the Yun-ling-shan system.

The higher peaks of the central ranges are from 9,000 to 14,000 feet above the sea, but, as a rule, lower elevations are common, the ranges are not so well accentuated as those further west and the relative heights between the valleys and the crests are less. Plains are of more frequent occurrence and on them many of the cities are situated. The streams of the western portion drain into the Mekong and the Red River, and the watershed between the latter and the Yangtze is followed approximately by the main route to the capital, Yunnan Fu. The tributaries of the Yangtze flow north and have dissected deep gorges for themselves before they enter it at elevations of between 2,500 and 4,000 feet.

In eastern Yunnan, from the meridian of the lakes to the borders, the eastern curve of the arc is found as a series of more or less regular chains running north-north-east and south-south-west. These ranges tend to become higher as they approach the Yangtze region. Here heights of 8,000 to 11,000 feet are reached. About the lakes 6,000 to 8,000 feet ridges prevail, further south towards Tongking they are lower still. The plains in the vicinity of the lakes have an average elevation of 6,000 feet.

In the extreme east of Yunnan, a series of lower ranges separated by small plateaus, stretch out towards Kuei-chou and Kuang-hsi. The greater part of the drainage eventually goes eastward into the West River of Canton.

In the south-eastern corner between the Nam Ti and the Clear River, there are said to be no definite orographical directions, and the surface is intensely eroded with a marked karstic effect.

Characteristic of Yunnan are its fertile plains, small flat-bottomed valleys lying snugly amongst the mountains. It has

been estimated that they form about one-fifteenth of the total area of the province and support one-third of its population. These plains are nearly all the dried beds of old lakes; occasionally the lakes or portions of them still exist; they date back to sub-recent times when the land stood at a higher level than it does now. They are always intensively cultivated and form a striking contrast with the rugged mountains surrounding them. Practically the whole of the walled cities are built on such sites at heights of 5,000 or 6,000 feet, while the ranges rise 3,000 or 4,000 feet above them.

The lowest land in the province is found in the bottom of the deep river cañons where they cross the southern frontiers. The Mekong leaves at 1,700 feet, the Red River at 500 feet and the Clear River at 700 feet above the level of the sea.

CLIMATE.

It is impossible to advance any general statement regarding the climate of Yunnan which would be applicable to the whole province. Its area is as large as that of some European kingdoms and it possesses a bewildering variety of topographic detail, broad open spaces alternate with exceedingly high mountain ranges, there are regions nourished by some of the greater rivers of the world and there are others parched and uninhabitable owing to the lack of water. I divide the province into three climatic zones:—

- (a) The Tibetan tract north of the 27th parallel,
- (b) The low plains and deep river valleys, mainly of the south and west,
- (c) The central elevated portion.

As I have no experience of the Tibetan tract I quote the views of Major Davies, "A country of very high mountain ranges the plains even rising to from 8,000 to over 12,000 feet. The climate here is naturally colder than other parts of Yunnan, and where heights extend from 6,000 feet on the river banks to over 15,000 feet on the hill tops, it varies much in different places. At the higher altitudes snow may fall in any month of the year, and many of the passes are liable to be blocked throughout April. In the plains the climate is less severe, but except in a shut-in river bed it never becomes hot." (D., p. 309).

In the low plains and deep river valleys of the south and west, the general elevation is from 3,000 to 4,000 feet with the rivers

flowing at heights of between 1,000 and 1,500 feet. The climate of these regions is not a good one. Conditions are almost tropical when compared with the more elevated areas. Fogs and rains are common, the temperature is fairly high and malaria is often prevalent.

But these two extremes are exceptional for by far the greater portion of Yunnan comes into the third zone, the plains lie at a general average of 6,000 feet with the hill tops rising some 3,000 or 4,000 feet above them. Practically all the big cities are situated about this level and the coal and salt fields occur in the same regions. It is to these tracts that the following remarks apply.

The climate is a most desirable one. The dry season begins in October and lasts into May. There is no great heat, and outdoor work may be carried on the day through without any particular fatigue caused by the temperature. The early morning mists of Burma and the Shan States are unknown, the damp heat often experienced later in the day in those countries is not experienced; taken all round it is bright and exhilarating weather. The coldest month of all is February when snow sometimes appears at 6,000 or 7,000 feet. Ryder registered a temperature of 17° F below freezing during this month at an elevation of 7,000 feet. I shall never forget the blizzards met with on the high ranges around La-li Fu at this time of the year. But those are exceptional circumstances. Frosts do occur in the winter but they are not of exceptional severity. During the cold months the Chinese warm their houses with charcoal or coal fires contained in iron braziers.

Leclère's remarks on this season in eastern Yunnan are worthy of attention. He believes that the climate of the mining regions of eastern Yunnan is the best in the whole of China and that it is really superior to that of most European countries. During the winter season Yunnan possesses a strong south-south-westerly wind which falls off during the night but blows with great intensity during the day. Dust storms are of frequent occurrence at such periods but as far as my personal experience goes they appear to be somewhat localised in their areas. There is hardly any rain during the winter south of Yunnan Fu. North of this latitude showers of rain, coming from the north, occur, but they do not descend into the deep Yangtze valley. Throughout the season, the temperature of the elevated regions remains a moderate one with very regular daily variations. February is usually the coldest

month. As the cold season advances the temperature gradually rises. The rainy season is usually preceded by showery weather, then the main break comes with tropical violence, lasting for two or three weeks (Le., pp. 456-461). For a month or six weeks in the high regions and for a longer period in the lower ones, transportation on the Chinese roads is completely stopped. I marched during the rainy season of 1909 from Yunnan Fu to Têng-yüeh and although it was certainly unpleasant, I did not find any difficulty in getting through, nor did any of my followers including several natives of India suffer from the experience. It is only in the lower regions that transportation is completely stopped. After the first outbreak the rains seem to develop a weaker character and although there are occasional days of rain following one another in succession, they are interspaced with periods of fine weather when field work may be carried on.

AGRICULTURAL PRODUCTS.

As is only natural in a land possessing such a diversity of surface, soil and climate, the agricultural products of Yunnan are varied. Rice is the most important food plant of the Yunnanese and all the plains of the province which can be irrigated are devoted to rice cultivation during the summer months. The young plants are grown in nurseries and are planted out in the flooded fields from September to November according to the state of the season. The slopes of the hills surrounding some of the plains are terraced for rice cultivation to a height which I have only seen equalled in the Himalayas. A variety of rice, called "hung mi" by the Yunnanese on account of its reddish colour, is sometimes grown in the hilly districts. It does not require artificial irrigation like the numerous white varieties and is grown on poorer soils. Glutinous rice is grown in some places, especially amongst the Shans who use it for food. The Chinese employ it in the distillation of spirit.

Wheat is not an important crop in Yunnan, except in the Tibetan areas of the north-west, where the plains are too high and the climate too cold for rice cultivation. At the same time, wheat is grown in small quantities in many other places, and wheat flour often adulterated with rice meal, is obtainable in all the larger cities. The awned varieties of wheat are very liable to be confused with barley. The cultivation of true barley is confined to the Tibetan zone, the principal food of the inhabitants of this region being

"tsamba" which is made by roasting barley and then grinding it into flour. Towards the end of my stay in Yunnan there was a large increase in the acreage under wheat owing to the restrictions which were being placed on the opium crop. Other summer cereals are maize, millet and buckwheat. Maize and millet are the principal crops in isolated hill tracts. Very little care seems to be needed to grow them and the hill slopes around the aboriginal villages are often devoted to their cultivation. I have seen no oats in Yunnan but Davies mentions that he saw a crop near Ch'-ü-Ching and I was told by missionaries that it is grown between Chao-tung Fu and the Kuei-chou frontier.

After the rice has been harvested on the plains, the fields are again sown with winter crops which until the end of December 1907 consisted of roughly, half poppy and the other half peas, beans, wheat and other products. White, yellow, green and black kinds of beans of all sizes were seen. They are largely used as food while the coarser kinds are dried and made into fodder for cattle and mules. Certain varieties of beans are also used for producing oil. Peas are obtainable anywhere throughout the winter. Besides being eaten raw, they are dried and ground into a flour from which a kind of vermicelli is made. This with bean curd forms the chief stock in trade of the food hawkers in the cities.

At one time poppy fields covered half the available land in the province and the production of opium was the most important industry. Yunnanese opium was declared by experts to be better than any of the Indian kinds and smokers preferred it before any other. In September 1906 the famous edict was issued from Peking which "commanded that within a period of 10 years the evils arising from native and foreign opium be equally and completely eradicated." In the winter of 1907-08 I noticed that poppy was still cultivated widely in Yunnan. In the early months of 1909 it had to all intents and purposes disappeared except in certain very isolated and mountainous districts. The poppy seed used to be sown in November either on paddy land in the plains or on the drier soils of the slopes, for it flourished well in both situations. The poppies bloomed in March or early April and the heads were ready for scoring about the end of April; when this operation was being done a white latex slowly exuded, but it soon dried to a brown syrup which was scraped away and allowed to dry in the sun.

Any account of the agricultural products of Yunnan however brief would be incomplete without a reference to tea. This plant is grown to the south of P'u-êrh Fu and Ssü-mao T'ing in the districts of Yi-pang, Yi-wu, Yu-lo, Man-sa and Man-la, in the Chinese Shan State of Keng Hung to the east of the Mekong river. The gardens are located both in the valleys and on the hill sides. The leaf is gathered in March and April and is dried in the sun. The gardens are to some extent in the hands of Shans, Akas, Pumans and other tribes-folk as well as the Chinese. After being brought into Ssü-mao, the leaf is sorted and blended and then treated by a steaming process which gives it the disc and hemispherical shapes seen in commerce. Davies has estimated the annual production at 15,000 mule-loads or approximately 900 tons (D., p. 96). Taking its average price at 3 pounds for one rupee, the value of the annual export would be Rs. 6,70,000 say £45,000. These figures can only be approximate, because most of the tea is sent to Yunnan Fu, the central mart for the leaf and only the small portions intended for the upper Lao States pass through the Ssü-mao Customs House. The price in Yunnan Fu when I was there averaged from $2\frac{1}{2}$ to $7\frac{1}{2}$ annas per pound, being entirely dependent on the quality of the blend. Inferior kinds of leaf can be bought in Ssü-mao itself direct from the merchants in the trade at cheaper rates (from 1 to 4 annas per pound), and very large quantities of these teas are annually disposed of to Tibetans, who come down in large numbers to Ssü-mao for this purpose. In November 1893, when high prices ranged for a time in the north, there were Tibetan caravans in Ssü-mao, numbering over 2,000 animals, engaged in loading tea, according to the official report of the Commissioner of Customs for that year. In the borderland between Yunnan and Tibet, discs of compressed tea sometimes take the place of silver in mercantile transactions.

The internal production of cotton in Yunnan is insignificant and as the whole population is clothed in cotton cloth often padded with the raw material, the importation of Indian yarn and Manchester goods is a most important trade. The greater part of Yunnan is much too cold for cotton cultivation and it is only grown in the bottoms of some of the deep river valleys and in the Southern Chinese Shan States.

Sugar is a crop of some consequence though it does not figure as an export to any extent. The cane will only thrive in the warmer

places and I never saw it doing well in localities over 5,000 feet above the sea. The canes are cut in the early summer and are crushed between heavy wooden rollers worked by buffaloes. The juice is boiled down almost to dryness and the brown semi-liquid mass poured into small moulds in which it solidifies. Some noteworthy districts for sugar are Shih-tien, Mo-hei, Pin-ch'uan Chou, and in general, places enclosed between high hills, where the climate is hot and not too dry.

Paper is made from a bamboo and also from a species of mulberry. The valley of the Shwe-li above Têng-yüeh is celebrated for its paper. The mulberry bark is steeped in water for a day or two and is then boiled with lime and afterwards carefully washed. It is then pounded between two heavy stones and disintegrated. The finer pieces are picked out and thrown into large vats of water. As more fibre is added the mixture is kept constantly stirred, until the finest pulp is suspended in the water. A frame made of bamboo is then dipped into the water, in such a way as to ensure a thin even layer of the paper pulp across it. The film of paper adheres together when dried and can be turned off the frame without tearing.

Fibre-producing plants are cultivated in some places, but not to anything like the extent to which they might be. After treatment they are used in the manufacture of string, rope and a very coarse kind of cloth. About 20 tons of hemp twine are exported from Yunnan to Burma through Têng-yüeh annually, taking the average export over a number of years. I do not know the botanical species of the hemp which yields these fibres, but the plant grows to a height of about 6 feet, and after being cut down it is allowed to rot in water, after which the fibres are easily extracted by hand. Mention may be made here of a curious kind of water-proof fibrous cloth which is made from the outer bark of a species of palm and which the Yunnanese call "tsung-pao." The production of this material must be enormous as it is used as a water-proof cover on all the caravan loads in wet weather, and also as a coat by the labourer in the fields during the rainy season.

Large numbers of water-proof hats are made in various places, such as Têng-yüeh, Ta-li Fu and Chiu-ya-ping, from the fine fibres of a bamboo and also from a species of coarse grass. There is a large local trade in these articles and numbers are exported to the adjoining provinces and to Burma and Tongking annually. 20,000

or 30,000 hats of split bamboo are by no means an unusual annual export through Têng-yüeh.

Tobacco is grown extensively for local consumption. Oil-producing plants of various kinds are raised for various purposes. Dye-producing plants used to be grown on a large scale, but the influx of the German aniline dyes had killed the industry when I was in the province. The only dye which I saw being made was a kind of indigo. The cultivation of this plant is not confined to any particular area as I found it scattered throughout the country.

A very large number of different kinds of fruit thrive in Yunnan; amongst others the following may be mentioned:—apple, pear, apricot, peach, nectarine, cherry, plum, orange, lemon, mulberry, citron, pomegranate, bramble, raspberry, strawberry, pine-apple, plantain, chestnut and walnut. There are extensive pear orchards around Yung-ch'ang Fu. Dried fruits of various kinds are prepared and exported. Walnuts are cultivated around Yang-pi and Hsia-kuan in Western Yunnan and are exported to Burma in large quantities. Over the years 1902—1909 the average annual export of walnuts through Têng-yüeh was 77 tons.

The Yunnanese are skilled gardeners and grow large quantities of vegetables for the city markets. As a race they are very fond of flowers and all kinds of shrubs and trees are cultivated for their blooms. The wild flora of Yunnan is a very varied one and European collectors have recently introduced many beautiful forms from its highlands into European gardens. It is not a well wooded country on the whole and great difficulty is experienced in obtaining wood of any sort near the cities. Large coniferous forests exist in the isolated areas but they serve no useful purpose. Timber for constructional purposes would make a profitable import from Burma if cheap railway transport was available.

Yunnan is essentially a grazing country, so little of the land is under direct cultivation, while so much of it has been denuded of all trees and scrub vegetation that immense areas are available for the raising of flocks, and the salubrious atmosphere together with the character of the soil, tends to the growth of grasses suitable for them. Writing on this subject as long ago as 1877, Davenport, in an almost forgotten report, stated: "It has a most suitable climate, neither too hot in summer nor too cold in winter, while the hills and surface generally are covered with luxuriant grass, which, like the grass in some of the Western States of North

America, is capable of affording, though dry and dead, due sustenance for animals throughout the winter, I mean of course uncut grass, hay being unknown in China, where the agriculturist has no instrument for cutting grass other than a sickle the arc of which is about eight inches in length. On this subject I speak with certainty, as the mules and ponies we used and met with on the road, as a rule, had no other food than the dry grass they ate after their day's journey was finished, although carrying heavy burdens up and down hills for many days consecutively. Moreover, the country is well supplied with water, while, the hills having a dry porous soil, sheep would probably not be liable to disease." These remarks are as true now as on the day they were written, and it is difficult to understand why the Chinese people do not practise stock raising far more extensively than is the case at present. The mules and ponies which are so largely used for transportation in Yunnan are reared principally in the north-western parts of the province. There is a large annual fair held at Ta-li Fu when numbers of animals change hands. The price of a good mule for caravan work varies a great deal from year to year, but as the demand is always active low prices are never prevalent. I do not care to make an estimate of the number of mules and ponies in Yunnan, which must be very large. In 1909, 65,409 pack animals with loads passed through the Custom's barrier in Têng-yüeh. 20,261 through Ssü-mao, and 69,974 through Mêng-tzū. Before the opening of the French railway, the number of pack animals which passed through Mêng-tzū was much greater, for example, in 1906 it was 295,300. At the same time, the figures may be misleading, as the returns do not state if these are individual animals or if the same caravans were not numbered over and over again, which is more likely to be the case. Caravans of Chinese mules travel great distances in the winter season and are to be found throughout the frontier districts of Burma, Northern Siam and even as far south as Tavoy.

Cows and buffaloes are to be found in every Yunnanese village. The cows are sometimes used in light ploughs, though the buffalo does most of this work. Bullocks are often used for transportation, especially by the Shans; and if time is no object, they seem to be a fairly efficient means, though they must be driven in the early morning and evening to avoid the heat of the day. The Chinese proper rarely make use of milk and do not slaughter

the cow for food, though beef can often be obtained in the cities where there are communities of Chinese Mohammedans.

Sheep-farming is rather an occupation of the Lolos and other tribesfolk than of the Chinese proper. Many of these people in the upper basin of the Red river and in the north-eastern prefectures possess very large flocks; the wool is the most valued product, but they do not know how to weave it into clothes. Felt rugs, carpets and coarse blankets, as well as the thick woollen mats which are sometimes used to protect mule loads in bad weather, are made from wool. Some of these articles are valuable items of export; 1,780 felt carpets were exported through Ssü-mao in 1909; in other years the number has been as high as 4,116. About 20,000 felt carpets used to be exported through Têng-yüeh annually up to 1914. There is a very bright future for trade in things of this kind, for markets are ever present in Burma for any agricultural products which Yunnan can spare. Yunnan is capable of raising hundreds of thousands more sheep than it does at present.

The Chinese use the bones of animals as fertilizers and also for the manufacture of buttons, dice, knife-handles, small boxes and chop-sticks. Horns of the water buffalo and ox are made into various domestic articles such as combs, brush-backs, shoe-horns and cups, the material being worked up in a lathe. Cow and buffalo horns are exported to Burma and French Indo-China. About 200 tons of horns were exported from Têng-yüeh per annum before the war. In addition to this there are exports of hides. The annual export of hides through Têng-yüeh alone amounted to between 150 and 200 tons per annum previous to 1914. This, however, does not by any means represent the number of animals which have been slaughtered or have died during the year, for large quantities of hides are required by the Chinese glue and leather makers in the province. The leather is largely used in the manufacture of saddlery and for the soles of boots. In this connection it may be well to point out that the hides from Yunnan would command a far higher price were they treated more carefully before leaving the country. Any process of pickling or salting appears to be unknown, and after being removed from the dead carcass the fresh skins are simply pegged out tightly in the sun and left to dry; the holes made by the pegs and the creases caused by folding the skins to form them into suitable loads, detract much from their appearance and value in the foreign market.

Fresh pork forms the staple meat food of the Chinese population, and great numbers of pigs are reared in every village community. The Yunnan pig is black and grows to a large size. They are fed on paddy mash, beans and the waste product of oil mills, kitchens, etc., but they are also allowed to scour about the fields and villages, where they act as scavengers and devour any refuse they can find. Large numbers of hams used to be exported through Mêng-tzü and Têng-yüeh. They can be obtained in Bhamo, where a ready and profitable sale is available. The two famous localities for Yunnan hams are Ho-ching and Hsüan-wei Chou. Pig bristles are exported from Ssü-ch'uan in large quantities to foreign countries, and there is little doubt that a similar trade could be started in Yunnan.

Poultry including hens, ducks, geese and turkeys are reared by the Yunnanese for domestic consumption. Duck feathers form a profitable export from Ssü-ch'uan and a market could be found for them from Yunnan.

The highlands of Yunnanese Tibet are the home of numerous fur-bearing mammals, which are hunted for the sake of their skins. Skins of foxes, lynx, wolf, civet, wild sheep, and goat are brought to Ta-li Fu and after passing through the hands of the furriers are placed on the market there. Southern Yunnan supplies the skins of tigers, leopards, wild cats and monkeys while the ordinary goat and sheep skins are also prepared for sale.

As long ago as the 16th century the musk of Yunnan was sought for on the South China coasts not only by native merchants but by Portuguese and others from Europe as well. At this time it was carried down as a rule through Tongking, and after sale to Cantonese merchants was then taken to Macao to be retailed. The musk deer (*Moschus moschatus*), the abdominal glandular pouch of the male of which furnishes the secretion, is known to the Chinese as "tchai tse," and used to be found in the mountains of Upper and Central Yunnan, in Kuei-chou, in northern Ssü-ch'uan and in Tibet, but for all practical purposes the deer is now practically exterminated, except in Tibet, from which country large quantities of musk are still sent into Ssü-ch'uan *via* Ta-chien-lu and Sungpan, and smaller quantities into Yunnan *via* Ba-t'ang and A-tun-tzu. Animals from five to six years of age are said to yield the best qualities of musk, and as the material readily lends itself to adulteration, great care is needed in buying it. As it is so easily

concealed and carried, there are no reliable figures as to the exact amount of its production, on account of smuggling. In recent years a representative of a French house of perfumers (Pinaud's of Paris), has been stationed in Li-kiang Fu, where he buys up any musk coming into Yunnan from the north. I saw this gentleman (M. Perronne), in May 1910, and he informed me that it was now exceedingly difficult to buy musk in these regions owing to the higher prices which could be obtained in Ssü-ch'uan.

The last recorded export of musk from Têng-yüeh was in 1912 when 10,356 lbs. were sent away. Its value works out at Rs. 28 per oz., a price which shows little variation on that given by the Lyons Mission.

White and yellow wax are exported through Mêng-tzū and Ssü-mao, and are also largely consumed internally. The yellow wax is a true beeswax, the product of the ordinary bee. Apiculture is common everywhere and hives made from the hollow trunk of a tree with the ends stopped up with wood and clay are often seen in the country districts. The insects are also kept in old walls of barns and houses. Honey is cheap, but is not often met with as a food stuff, except amongst the Lisu and other poverty-stricken tribes. According to Hosie, yellow wax is employed "in rubbing the strings of the card figure in silk weaving; it is also used to a limited extent in candle making, and the carpenter finds it a good furniture polish. Another, but minor, use is the polishing of the string of the cord employed in carding raw cotton after ginning. This keeps the wool from adhering to the string."

The white wax is the product of an insect (*Coccus pela*) which is reared in the districts about the Kuei-chou frontier on the road from Wei-ning to Yunnan Fu, and also in the Hui-li Chou district in the southern part of the Chien-ch'ang valley. To look at, the insects seem to consist of a mass of small grubs enclosed by soft rounded brown shells which are carried about the land packed in small straw compartments. These are fastened on to suitable trees, when the insects are said to hatch out and spread above over the branches, depositing wax wherever they go. The wax is collected from the branches and cases by scraping and boiling, and it is used principally as an outer coating for Chinese candles, as it melts at a higher temperature than the animal fats from which such candles are made, and so prevents the candle guttering when it is burning. Hosie also states that it is used for imparting a

gloss to the higher grades of paper. In damp clammy weather a board thinly coated with white wax is drawn along the surface of satin and silk warps in silk-weaving establishments to facilitate the passage of the strands through the loops. It is used for adding a lustre to cotton cloth, and as a polish in jade ware, "in the daintier articles of furniture, such as small dressing-cases and cabinets, and it is universally used by the medicine shops for coating pills, and thus preserving the active properties of the drugs of which they are composed."

According to Davies the price near Wei-ning Chou is 20 taels (about Rs. 31), for a man's load of 50 or 60 lbs. of insects. There is little doubt that the finer varieties of paraffin wax would do as well as this white wax for certain of the uses to which it is put, and there is an opening for an import market of Burmese paraffin wax therefore in Yunnan.

Silk is produced in Yunnan on a small scale, but the yellow silk which is exported through Têng-yüeh, and which forms by far the most valuable export, probably all comes from Ssü-ch'uan where it is a great and very valuable industry. In many places in Yunnan I have seen the cocoons laid out to dry in the sun, and in a few others I have seen the silk being spun from them. The provincial Government tried to improve the silk industry in various ways. Orders were issued to the district officials to encourage the cultivation of the mulberry as much as possible, and a good example was set at Yunnan Fu, where many thousands of young trees were planted. Improved patterns of looms were set up in the provincial capital, and Cantonese weavers were engaged to train classes of students in the art.

INTERNAL COMMUNICATIONS.

Yunnan suffers greatly from lack of efficient ways of transportation. Though some of the greater rivers of the earth flow through it, there is no waterway in the interior which is of any practical service for boat transportation on a large scale, much less for steamers of any kind.

The Yang-tze is navigable by boat to Sui Fu (lat. 28° 45', long. 104° 35'), one stage from the Yunnan boundary, but elsewhere rapids and rocks make navigation impossible, except on short reaches, and then at considerable risk. The Red river is navigable by boats to Man-hao, just inside the southern frontier of Yunnan,

and after that it is useless for similar reasons, though it penetrates into the very heart of the land. The Mekong, Salween, and Shweli need not be discussed. They flow swiftly in rocky channels traversed by rapids and cataracts, liable to great floods, and often at the bottom of precipitous cañons into which the light of the sun only penetrates for an hour or two in the day.

The mountainous nature of the land and the inertia of the government are jointly responsible for the bad and sometimes dangerous condition of the roads in Yunnan. Wheeled traffic is for all practical purposes non-existent, and the transportation of goods is effected by the use of pack mules, bullock trains, and, more rarely, porters. The roads of Western China have been abused by every traveller and writer on the land from the time of Marco Polo onwards, and it is unnecessary to add to the great volume of vituperation already in existence though the memory of many a weary march invites one to do so.

Zigzagging up the steep mountain sides, wandering across the plains, the Chinese paved roads extend for thousands of miles. The paving stones are of all sorts and sizes, and often no repairs have been done since they were first laid down, so that large spaces separate the stones in some places, and in others the impact of countless iron-shod hoofs has in the long course of time drilled a hole right through them, so that one appreciates the Chinese maxim regarding the roads of the land, "Good for ten years and bad for a thousand."

On the paved mountain tracks riding is out of the question, and after a shower of rain the stones become so slippery that pack animals can only keep a footing with difficulty. The traveller in despair often takes off his boots to avoid falling on the flat stones, only to be cut by the sharp and jagged edges of the broken ones. Add to this that the roads are as often as not cut along steep hill sides with a precipice on one hand and a slope which may serve for a landslide on the other, and the risks the merchants run in carrying goods from one part of the country to another may be well imagined. In the plains the tracks always go around the paddy fields, never across them, and every farmer uses them as waste irrigation canals into which to turn the surplus water from the crops. Very often, in order to avoid the paved roads, earth tracks are made alongside them, but, these are only available in the dry season. In the rains the overland trade is

at a standstill, as it is impossible to get the pack caravans about the country when the earth paths are morasses, when every stream overflows its banks, and the low-lying areas are flooded. Mention must be made of the wonderful suspension bridges of the Chinese which are to be seen where the main trade routes cross the larger rivers such as the Mekong or Salween. Eight or ten iron chains of massive construction are stretched rigidly across the valley some distance above the water and firmly fastened in massive masonry on each side. The road is carried across on a gangway of wooden planks with a protecting parapet of railings on each side. The bridges are built, at the expense of the merchant guilds who use the road, and although they sway about somewhat, they can carry a heavy load; animals can cross in perfect safety two or three at a time.

When the nature of the roads in Yunnan is appreciated and the crumpled up character of the great mountain ranges with the river gorges between realised, it becomes a matter of wonder not that the external trade of Yunnan is small, but rather that any exists at all.

TRADE ROUTES.

There are four great trade arteries into Yunnan. These are:—

- (1) The Bhamo-Têng-yüeh route—the main trade route from Burma—which it is necessary for me to describe in greater detail. Goods travel from the sea coast at Rangoon by rail to Katha *viâ* Myohaung, Sagaing and Naba, and thence to Bhamo (lat. $24^{\circ} 15'$, long. $97^{\circ} 15'$); or by steamer on the Irrawaddy river from Rangoon to Bhamo *viâ* Mandalay. Bhamo is three days journey from the Burma-China frontier, and is connected with Têng-yüeh, the treaty port of Western Yunnan, by a mule road 112 miles in length. The time taken by loaded caravans to traverse this distance varies from $7\frac{1}{2}$ days under the best conditions to twice as long at the worst. Têng-yüeh is connected with Ta-li Fu on the shores of lake Erh Hai by a well-known road 170 miles long. It is not my intention to describe this route fully, but rather to point out the difficulties of communication along it, and the recent attempts which have been made to improve it. It is probably more or less

in the direct line of the old trade route which has been used for centuries, and it is certainly the direction followed by Marco Polo at the end of the thirteenth century, and so vividly described by the famous Venetian. It forms part of the Imperial highway by which officials from Peking reach these remote parts of the Republic, and by it the Burmese missions travelled when they conveyed the tribute from the kings of Burma to the emperors of China. Full accounts of it are to be found in the writings of Anderson, Margary, Baber, Gill, Jack, Davies, Ryder, Lord Ronaldshay, and many others. After crossing the level plains of the Irrawaddy from Bhamo the road enters mountainous country beyond Mo-mouk and proceeds along the south bank of the Ta-ping river, through thickly wooded and very hilly country until the frontier is reached at Ku-li-hka, after crossing which it descends to the level plains of the Chinese Shan State of Kan-ngai. An alternative and older road proceeds along the north bank of the Ta-ping, but it also comes down into the Kan-ngai plains near Man-yun (the scene of the murder of Consul G. A. R. Margary in 1876), a few miles from the other. The overland telegraph line used to proceed along this road but has now been taken across to the other. For some years after the opening of the new road the muleteers engaged in the trans-frontier trade preferred to travel by the older and better known route, which although slightly longer and more difficult was convenient because supplies were easily obtained and grazing grounds were available. The tendency now is for caravans to take to the new road. In my own experience this has been so, and I am inclined to put it down to the gradual formation of groups of houses with hostleries kept by Yunnanese Chinese chiefly, who cater for the wants of the men and animals in the caravans; and also to the excellent nature of the road itself and the bridges, which are kept in repair by the engineers of the Bhamo district.

For two or three marches beyond the frontier the road crosses the Kan-ngai plains, and the gradient is easy enough,

though the road has nothing to distinguish it from the ordinary Chinese road across level ground. It would be difficult to imagine a greater contrast than that presented by the high, densely wooded, almost uninhabited Kachin frontier ranges on the one hand, and the open paddy plains surrounded by rounded granite hills on the other. These are cultivated wherever irrigation is possible, and contain scores of peaceful Shan villages each in its grove of trees. On each side of the narrow plains rise the rounded grassy slopes of the high granitic ranges which bound it. Tree vegetation is as a rule absent, indeed throughout Yunnan wherever the population is fairly large the forests and undergrowth have disappeared. This is a well-known feature of Chinese civilization, and has risen partly for strategic reasons, and partly on account of the necessity of wood for fuel.

- A high dividing range separates the valleys of Kan-ngai and Nan-tien, and the Ta-ping here flows through the deep and narrow Hu-lu-ko gorge. The road winds over this range and then descends to the plains of the state of Nan-tien, which are by no means so rich as those of the sister state. The cultivated area is not so extensive, and a poor Chinese element predominates over the Shan in the population. After passing through Nan-tien the road commences an ascent which culminates in the high level valley in which the walled city of Têng-yüeh is built at an elevation of 5,370 feet above the sea. Têng-yüeh is the place of residence of a British Consul, a Commissioner of Customs of the Chinese Maritime Customs Service, whose duty it is to take account of all the trade passing through and to collect the taxes on the same (European British subjects have held this post since its formation), and various high Chinese officials, including the Tao Tai of the I-Hsi-Dao in the old Imperial days, or Commissioner of the Western Division of the province, and a Chen Tai or General in the Chinese Army.

The intervening 170 miles between Têng-yüeh and Ta-li Fu are of a very different nature to those between Bhamo

and Têng-yüeh and a series of high mountain ranges and deep narrow intervening valleys have to be crossed. Lilley in 1907, after careful calculation, stated that the ascents on the road pass through a total vertical height of 26,680 feet, while the descents fall through 25,250 feet. The total rise and fall of the road amounts, therefore, to no less than 51,930 feet. The net difference in elevation between Têng-yüeh and Ta-li Fu is only 1,430 feet, which means that the road, in the course of its length of 170 miles, passes through a vertical distance of nearly 10 miles. No less than eight great depressions with high ranges between them are passed in the short distance, and although there are only three river basins included, *viz.*, the Irrawaddy, Salween, and Mekong, some of the tributary streams are quite large enough to be regarded as independent streams.

Under the articles of the Man-waing agreement of 1902, the proceeds of the mule tax, which is levied per head on every mule which crosses the frontier may be devoted for the repair, upkeep and policing of roads of the Têng-yüeh and frontier areas, as well as for other municipal and indemnity purposes. This tax was, prior to 1902, collected by the Pao-chang office, which used to keep up the obsolete Trade Protection Levy Corps, and by the Sawbwas or chiefs of the States through whose territories the trade routes ran. The tax is now collected by the Customs Office in Têng-yüeh (founded in 1902), and the funds, which are all allotted to the Sawbwas, are sent to them, in return for which they have to guarantee the safe passage of caravans through their States. This agreement seems to work well on both sides.

A road committee met from time to time to discuss questions affecting the trade routes. This committee was made up of the Commissioner of Customs and various Chinese officials, while His Majesty's Consul in Têng-yüeh also had a seat. In 1905-06 an attempt was made to improve the road between Têng-yüeh and Yung-ch'ang Fu where it crosses the Kaoliang Shan, the great mountain chain which separates the valleys of the Shwe-li and Salween

rivers. In the winter of 1909 a start was made to improve the road between Têng-yüeh and the Burma frontier at Ku-li-hka. A proclamation was issued by the Commissioner of Customs (at that time Mr. F. W. Carey), and the local Chinese contractors were invited to undertake the work. There was practically no response to this appeal, and the work was eventually undertaken by the Customs Department, a subordinate officer being allowed by the Inspector-General in Peking to use six months' leave to take charge of the duty. I had an opportunity of seeing part of the reconstructed road in April 1910 when I was returning to the Burma frontier, and, being well acquainted with its former state was in a position to appreciate the improvements. Repair and maintenance work have been regularly carried out since then and in 1914, an experienced engineer, lent by the Burma Government commenced a survey for the realignment of the road between Kan-ngai and Têng-yüeh.

- (2) The Tongking-Yunnan Railway route. The second great road into Yunnan and, indeed, the most important as far as present day trade is concerned, is the railway through Tongking into Yunnan. This line starts at Haiphong, on the shores of the Gulf of Tongking, and runs to Lao-kai (lat. $22^{\circ} 30'$, long. $103^{\circ} 57'$), on the Tongking-Yunnan frontier, and thence to Yunnan Fu, the capital of Yunnan. In earlier days a well-known trade route was followed by caravans from Yunnan Fu into Tongking, but the completion of the French railway in the early summer of 1910 has, of course superseded this; it is described on a later page.
- (3) The Yangtze route. Another very important route into Yunnan is that which passes through the heart of China up the Yangtze river—the route followed by the officials deputed to the province from Peking, and the direct way of communication with the capital. Steamers can ascend the Yangtze as far as I-chang, and thence junks proceed to Sui Fu in Ssü-ch'uan, but only one stage from the Yunnan boundary. After marching over this road for 25 days Lord Ronaldshay wrote: "A route which

may undoubtedly claim the distinction of being the most difficult and most inhospitable of all the routes which serve as the main lines of communication in this part of China. Until the mineral wealth which it possesses is properly and systematically developed, this portion of Yunnan can be of no commercial value, nor can I imagine any line of country less likely to excite the enthusiasm of the railway engineer."

The Blackburn mission passed over this route in 1897 and described it as a country of "alternating bare, wind-swept downs and precipitous cañons." "On 31st March we travelled 25 miles without seeing a village, and there was no work for us to do—a commercial mission in the Sahara. In truth from Lao-wu-tan to Kungshan the country, at present, is of no possible value for commerce. The people are very poor, and clad exclusively, when clad at all, in Shah-shih cotton cloth, but they can scarcely afford sufficient clothing." Speaking of the country a few miles to the east of the trade route in the Tung-ch'uan Fu area, Major Davies, with all his extended acquaintance with the geography of Yunnan and other countries, remarks: "I do not think I have ever seen such a mass of steep broken hills as this country presents. The hillsides are very barren and dry, and many of them are too steep to be climbed, so that the roads have to follow the beds of streams."

I give these quotations because this is one of the few districts in Yunnan which I have not crossed myself, and I desire to correct an erroneous idea which is prevalent that future expansion of railways lies in this direction chiefly. This idea has arisen because it is the shortest route between Yunnan and the Yangtze valley proper, but it never existed except in the imagination of theorists unacquainted with the real state of the problem.

- (4) The West River route. The least important of the four great routes into Yunnan is the one which leads up the West river from Canton, through the provinces of Kuangtung and Kuang-hsi to the borders of Yunnan. Boats can ascend as far as Pai-sé T'ing (lat. 23° 55', long. 106°), one day's march from the border of Yunnan.

Other routes, of course, enter the province though they are not to be compared in importance with those I have already mentioned. They include the following roads from Burma:—

- (1) Myitkyina to Têng-yüeh *viâ* Sadon and Ku-yung-kai, or *viâ* Sadon and Chan-hsi. This track is usually followed by the caravans from the jade mines.
- (2) Bhamo and Nam Hkam in Burma, to Têng-yüeh and Yung-ch'ang Fu, *viâ* Che-fang, Mang-shih and Lung-ling Ting, a quicker way into the British Northern Shan States than the Bhamo-Têng-yüeh route, and, therefore, often taken by coolies and others who find employment in the towns, mines, and forests of the Northern Shan States.
- (3) The road from Lashio (the railhead of the Shan States branch of the Burma Railways), to Ta-li Fu and other cities in Central Yunnan, *viâ* the Kunlon ferry across the Salween river and Yun-chou. This is important because it has been greatly advocated as a proposed railway line into Yunnan from Burma.
- (4) The route from Kengtung in the British Southern Shan States into Southern Yunnan, *viâ* Kenghung and Ssü-mao. The latter city is the "treaty port" of Southern Yunnan, and this road takes the trade between Burma and the cities of the southern portion of Yunnan.

THE TRANS-FRONTIER TRADE OF YUNNAN.

Statistics of the foreign trade of Yunnan are available from three sources; the annual reports of the Chinese Maritime Customs Service dealing with the three "treaty ports" of Mêng-tzŭ, Ssü-mao and Têng-yüeh; the annual notes on the trans-frontier trade of Burma published by the Government of Burma, and the annual reports of His Britannic Majesty's Consular officers in Yunnan Fu and Têng-yüeh.

The treaty port of Mêng-tzŭ was opened in 1887 and here the import and export trade with Tongking is recorded. Ssü-mao records trade between Yunnan, the Southern Shan States, and the upper Laos. Têng-yüeh, opened as a treaty port in 1902, is on the main trade route between Burma and Western China.

No apology is needed for reviewing the trade of a port which depends so largely on a mineral industry as Mêng-tzū. Mêng-tzū does. Metallic tin from the Ko-Chiu mines has often represented over 90 per cent. of the total value of its annual export trade. The money received by the sale of tin is used to purchase cotton yarn and other foreign imports, and any dislocation of the tin trade, caused by a fall in the price of the metal or other disturbance, is at once reflected in the general trade of the port. Thus the low local price of tin in 1913 resulted for a short time in the total stoppage of trade and the Commissioner of Customs reported that the decrease of some £90,000 worth of imported cotton yarn was partly due to this cause. In 1900 the annual export of metallic tin slabs from Mêng-tzū totalled 2,899 tons, since then it has gone on increasing year by year, with very few fluctuations attaining a total of 9,798 tons in 1912. It has been said that the tin industry is "the staple resource and mainstay of the province" and there is some truth in the statement.

Other metals exported from Yunnan through Mêng-tzū include antimony, both regulus and refined, spelter and manufactured iron in the form of pans, nails, etc. The antimony comes from the prefectures of Kwang-nan and Kai-hua, the former one being on the borders of Kwangsi. Rights were granted to a Chinese concern to mine and smelt the ores in 1909. In 1913, 427 tons were exported and in 1914, 335 tons. 893 tons of spelter were exported in 1913 falling to 304 tons in 1914. In 1900 the total weight of native iron manufactures exported was about 20 tons, but since then they have gradually fallen off to insignificant quantities.

Other important exports from Mêng-tzū include tea, hides, Chinese medicines and cunao. The chief imports include cotton yarn both Indian, Japanese and Tongkingese, cotton goods of all kinds, velvets, blankets, Chinaware, clothing and hats, aniline dyes, lamps and lampware, Japanese matches and kerosene oil, both American and Sumatran. Exports of lesser note include horns, hams, white and yellow beans, china root, native-made namkien cloth, edible fungus, marble, potatoes, native liquor, soy, brown sugar, vermicelli and macaroni and white and yellow wax. It must be noted that the port itself is merely a distributing centre for places far distant and that transit goods often amount to 70 per cent. of the total importations.

Reviewing the total annual value of the import and export trade of the three treaty ports Mêng-tzŭ, Ssŭ-mao and Têng-yŭeh for the 10 years preceding the outbreak of the war in 1914, we find that between 1904 and 1909, the Mêng-tzŭ figures fluctuated between $9\frac{1}{2}$ and $10\frac{2}{5}$ millions of taels. In 1909 Mêng-tzŭ was placed in direct rail communication with Haiphong and the value rose to nearly 11 millions of taels. In 1910 the extension of the railway to Yunnan Fu was opened for through traffic and trade rose to $11\frac{3}{4}$ millions of taels; from that year onwards there was a gradual increase to 1913 with $19\frac{7}{10}$ millions of taels or approximately £2,977,000.

In 1904, the value of the import and export trade of Ss-mao was 205,000 taels approximately. It fell slowly to 129,000 taels in 1908 and then began to increase, attaining a maximum of 263,000 taels in 1912 and falling again to 244,000 (£33,800 approximately) in 1913. For all practical purposes the trade of this port is stagnant.

The total value of the merchandise imported and exported through Têng-yŭeh in 1904 was 2 millions of taels approximately. It fell to $1\frac{1}{2}$ millions in 1909, rose to 2 millions in 1910, fell again to $1\frac{7}{10}$ millions in 1911 and rose to 3 millions of taels in 1914 (£400,000 approximately).

The war has affected the trade of all three ports, the last published figures (1916) being 15 millions of taels for Mêng-tzŭ, 184,000 for Ssŭ-mao and $2\frac{3}{10}$ millions for Têng-yŭeh.

In 1913 the total value of the Mêng-tzŭ trade was almost 6 times the value of the Ssŭ-mao and Têng-yŭeh trade combined.

In 1895 Davies visited Ssŭ-mao and afterwards wrote, "I cannot imagine it will ever be of any use to foreign merchants." The trade returns of the port since then prove that his opinion was correct and I see no reason to come to any different conclusion to-day. Its principal exports are a few agricultural products of the country and a little manufactured iron-ware which makes its way to the upper Laos. Its most noteworthy import is raw cotton.

The trade of this port requires more detailed treatment, because it is the chief market through which commerce has been exchanged between Burma and Western China for centuries and because it is in this market and along this route alone that any future expansion can take place.

By the Burma Convention of 1894, general traffic across the Burma-Yunnan frontier in munitions of war, opium and spirituous liquors is prohibited as well as the importation from Burma into Yunnan of salt and the exportation from China to Burma of rice and grains of every kind and cash ; under the same Convention the duties leviable on foreign goods imported into China from Burma are only 70 per cent. of the duties leviable on similar goods entering China by any other route, while the duties chargeable on Chinese exports across the frontier into Burma total only 60 per cent. of the tariff in force throughout the rest of the Republic.

Again, Têng-yüeh is favoured by a tax which is imposed on trade of all descriptions. The mule tax of 0.50 taels on every animal bringing import cargo and 0.25 taels on each animal carrying export produce, provides funds which are ear-marked for repairing, maintaining and guarding the routes of the district and especially the frontier road to Bhamo, and every traveller with any experience of the road knows how admirably these funds have been expended.

Yet, in spite of these advantages, there has been no noteworthy expansion in commercial dealings between the two countries. Writing in 1912, the British Consul stationed in Têng-yüeh remarks, "During ten years since the establishment of the Customs House under foreign control there has been no regular development of trade, the total value having fluctuated within the narrow margin between a minimum of £203,000 and a maximum of £299,000. As a matter of fact in 1912, the value increased to £382,584 and in 1913 to £473,000 which is a record since the port was opened. These increases are due in part to the rise in the exchange value of the Haikwan tael. but are none the less gratifying as far as they go. It is believed however, that the trade between the two countries is capable of very much larger increases.

China, as a whole, is a self-supporting country and the tendency at the present time, is for her to become more so. The foreign merchant can only hope to market those products which the Chinese people cannot make for themselves in large enough quantities to satisfy their own demands, or in luxuries of the outside world which contact with the West has taught the East to desire. Sir Robert Hart meant the same thing when he wrote "to dispose of their merchandise in proportion to the new tastes they introduce, the new wants they create, and the care they take to supply what the demand really means." Yunnan is no exception to the rest of the

provinces, though the question is complicated by its land-locked position, by its poor internal roads, and by the small purchasing power of the population, a result of neglected mineral development and, in recent years, of anti-opium legislation; this deprived the peasantry of ready money which was at one time used in the purchase of imported articles.

The Têng-yüeh trade returns issued by the British Consul and based on figures supplied by the Customs House, show the following values over the 10 years 1904-1913 :—

—	Import.	Export.	TOTAL.
	£	£	£
1904	251,249	48,542	299,791
1905	222,033	36,428	258,461
1906	185,643	44,424	230,067
1907	205,610	75,874	281,484
1908	109,713	65,736	235,449
1909	142,324	59,610	201,934
1910	194,737	74,976	269,713
1911	166,733	60,021	226,754
1912	278,488	104,076	382,564
1913	362,772	110,302	473,074

According to the "Report on the Trans-frontier Trade of Burma for 1916-17, the trade with Western China is practically the trade of Yunnan with Burma between the main centres of Têng-yüeh and Bhamo. The figures of the trade in merchandise between Burma and Western China taken from these reports over the period 1905-1913 are as follows :—

—	Import.	Export.	TOTAL.
	£	£	£
1905-06	114,999	220,075	335,074
1906-07	114,054	242,088	356,142
1907-08	113,019	273,457	386,476
1908-09	112,377	272,697	385,074
1909-10	107,474	263,368	370,842
1910-11	122,063	302,779	424,842
1911-12	120,869	239,674	360,543
1912-13	149,040	421,550	570,590
1913-14	192,692	402,722	595,414

A comparison of the two tables suggests that, contrary to the statement quoted above, a considerable volume of trade passes in both directions without coming through the Têng-yüeh Customs House. There are several trade registration offices in the Bhamo district which not only collect returns of the Western Chinese trade but also that of certain parts of the Northern Shan States as well. There are also routes leading across the frontier into Yunnan radiating from the nodal points of Bhamo and Myitkyina which do not touch Têng-yüeh at all. Again, even if these are left out of consideration and only the trade returns taken into account which have been registered at stations on routes known to lead to Têng-yüeh, it is impossible to correlate with any approach to equality the figures of the Burma returns with those of the Chinese Customs in Têng-yüeh, because certain amounts of trade, especially exports of manufactured goods from Burma, are absorbed in the intervening country, that is in the Kachin Hills and the Chinese Shan States. After a careful analysis of the Burma returns I am reluctantly forced to conclude that it is impossible to separate accurately the through trade, between Bhamo and Têng-yüeh from them, just as it is also impossible to estimate from the same publications the value of the trade between the Southern Shan States and Ssü-mao. In any consideration of this important question one is compelled to use the Chinese figures and it is fortunate that such reliable statistics are available for study.

The more interesting features shown by both tables are the low trade values for the two years 1909 and 1911. 1909 marked the minimum point of the decade. In that year the cultivation of the poppy had ceased for all practical purposes and the Yunnan populace had not adapted itself to the new conditions. About the same time an outbreak of plague in Bhamo interfered considerably with the overland traffic. In 1911, the Chinese Government of the day was overthrown and the general insecurity of life and property caused by the revolution is held to account for the fall in trade values, helped locally by a boycott of British goods in Yunnan Fu and by the collapse of the Salween bridge on the main artery of trade between Têng-yüeh and Ta-li Fu. The rise in the total trade values in 1912-13 is a reflection of the more settled state of the province and the return of confidence amongst its traders.

Perhaps the most important point brought out by an investigation of these figures is that the railway which put Yunnan Fu

into connection with the sea at Haiphong in 1910 has, contrary to the opinion of all authorities, had no adverse effect on the Burma-Western China trade up to the present time. I shall return to this question in a later paragraph.

The value of the overland trade then, reached a record in 1913; in the early months of 1914 further prosperity was witnessed and the record of 1913 promised to be exceeded, when the war broke out and this remote trade route like most others was at once adversely affected.

In the years 1904, '05 and '06 the value of the export trade from Têng-yüeh was $\frac{1}{7}$, $\frac{1}{8}$ and $\frac{1}{4}$ that of the Têng-yüeh's export trade. import trade respectively. During the rest of the decade the proportion rose and the value of the import trade averaged 2.6 times that of the export. The average figures taken from the Burma lists for the whole decade for the total trade with Western China, excluding specie, was 2.1. The principal export is raw yellow silk from Ssü-ch'uan which rapidly increased in quantity and value in the years preceding the war, reaching about 90 tons with a value of £76,560 in 1913. The rise and fall in the importation of this commodity depends on the state of the market in Burma, as the material is almost entirely used in the weaving of silk garments in Burma. The beautiful silks of Amarapura and Tavoy are alike made from this imported raw stuff. The competition of cheaper machine-made Japanese silks seems to have left the better classes of indigenous hand manufacture untouched and it would appear that there is every prospect of a continuous market for it.

After raw silk, hides form the next export in order of value. The value of this trade has increased during the decade and still more since then, owing to the greater demand from Europe. In 1913, 230 tons of hides, worth £11,821, were sent to Burma from Têng-yüeh. Complaints are often heard about the bad condition and packing of Yunnan hides, but it is very doubtful if anything can be done to remedy these defects.

Musk occasionally figures in the returns as a valuable export. Thus in 1912, 348 lbs. valued at £10,356 were sent out. The trade in musk is an erratic one. It is controlled by a famous Parisian firm of perfumers whose European agent periodically visits A-tun-tzu in Yunnanese Tibet and stays there until he succeeds in buying

sufficient for his purposes, when he returns to France with his valuable stock.

Another important product of the country is orpiment which figures in the returns every year. In 1910 over 500 tons were exported but since then there has been a decrease. In 1913 only 269 tons were sent out. The exact location of the orpiment mines had been a jealously guarded secret for a number of years but I succeeded in visiting them and making an inspection. The subject is treated at length in the second section of this report and all that need be said here is that there is no fear of the trade in this mineral becoming extinct through exhaustion of the deposits.

Felt carpets continue to be sent into Burma through Têng-yüeh in increasing numbers. In 1913 about 25,000 were exported of a value of £2,884.

Exports of lesser note include hemp twine, rain hats of split bamboo, walnuts, iron pans, brass bells, cow and buffalo horns and Chinese medicines. To those desirous of studying the returns of these and similar small articles the China tables are recommended rather than the Burma ones, in which a stereotyped classification conceals many of them in columns headed "Other Sorts" on "All other articles of merchandise."

Turning now to the import trade, we find that the most valuable article entering China through Têng-yüeh is cotton. The climate of the high uplands of Yunnan is too cold for the successful cultivation of the cotton plant, and as the Chinese wear cotton garments almost entirely, they are dependent upon the outside world for the supply of materials to make them. Attempts have been made to cultivate cotton in the Mekong valley and in the warmer parts of the Chinese Shan States, but it is very unlikely that indigenous cotton will ever interfere much with the imported article, which as far as Têng-yüeh is concerned is principally Indian cotton yarn. In 1913 nearly 5 millions of pounds of yarn, worth £234,000, passed through the Customs House. Large quantities of manufactured textile goods also go in, such as grey, white, British and Indian shirtings; American, Indian and English drills; T Cloths and plain cotton Italians. Smaller amounts of velvets and velveteens, woollens, woollen and cotton mixtures, towels, chintzes, prints, Spanish stripes, blankets and various forms of cheap ornamental cloths.

There is a large and growing market for kerosene oil in Yunnan. In 1913 nearly 40,000 gallons entered the country through Têng-yüeh alone.

The only mineral import is jade-stone and the quantity varies greatly from year to year, depending on the output of a particularly erratic type of native mining and also on the internal demand, which like most markets for precious and semi-precious stones varies with the general prosperity of the people. The jadeite is mined in the Mogaung subdivision of the Myitkyina district in Burma, exported in the rough and worked up, as far as Yunnan is concerned, in Têng-yüeh, where every street has a lapidary's shop and lathe. In 1913, 120,000 pounds were imported, worth £4,480. This value is purely a nominal one, because it is impossible to estimate the value of a lump of jadestone until it has been cut several times. Dealing in this mineral is very speculative and as such appeals to the Chinese sporting instinct. I have seen a boulder sold one day for a few rupees, appreciate on cutting to as many hundreds with a repetition of the same process on further examination.

Other imports include matches, umbrellas, various substances used in Chinese pharmacy and in cooking, enamelled ware, tin ware and miscellaneous small ware. A walk through the Têng-yüeh bazaar reveals a multitude of small articles coming under the last heading, cheap clocks and watches, mirrors, ribbons and laces, pocket knives, padlocks, leather belts, glass beads, cigarettes, candles, lamps and lamp-glasses, fans, musical instruments, tinned milk, biscuits and provisions, cheap confectionery, buttons, braid, cups and saucers, milk jugs, iron bowls, kettles, small metal boxes, scissors, ready-made clothes, hats and caps, soaps, perfumes and powders, medicines like quinine, santonin and boric acid, bandages and sticking plaster, threads and materials for embroidery, paints and pigments, cheap cutlery, galvanised iron and materials made from it, carpenters tools and toys. I have not attempted to make a complete list, but merely to indicate a few of the thousand and one wares which find a ready market in Yunnan. They may not appear much in themselves, but when one considers the vast quantities of similar articles which are sold in the bazaars of Burma and the Shan States every year, no doubt is left that a very large turn-over could be done in Yunnan. Most of these articles came from Germany and Austria before the war and it is interesting to note

that in 1914 the British Consul at Têng-yüeh reported that the commercial competition of Germany and Austria, chiefly in cheap lines of hardware and chinaware, had been almost extinguished and replaced, largely by Japanese goods. In the same connection I would point out the desirability there is for the representatives of the great import firms of Burma to visit Yunnan and study the markets there. The province in my time was being toured by German, Japanese, French and American business men on behalf of firms of their own nationality, but I never saw or heard of a British merchant visiting Yunnan.

Têng-yüeh itself has a population of about 10,000 souls. With its suburbs and adjacent villages it probably approximates 25,000. It is an agricultural population with a small proportion engaged in trading and a smaller percentage in jade-cutting, brick and tile making and mining. It is a healthy city and the populace is both peaceful and prosperous. Its chief importance lies in the fact that it is the distributing centre of the commerce of western Yunnan, for about three-fourths of the imported trade goes overland for final distribution from Hsia-Kuan, near Ta-li Fu. Hsia-Kuan is undoubtedly the commercial centre of the more prosperous portion of Yunnan. It lies 8 miles south of Ta-li Fu in lat. $25^{\circ} 35'$ and long. $100^{\circ} 10'$. Most of the merchants engaged in the Burma-Yunnan trade reside there, for the three routes from Burma, the Bhamo-Têng-yüeh, the Lashio-Kunlon Ferry and the Kengtung-Ssümao-Ching-tung roads meet those which continue to Tibet and Ssü-ch'uan in a north and north-easterly direction and to Yunnan Fu and other areas to the east. The place is a very important objective from the railway point of view.

Every competent authority has urged that the only way in which the overland trade between Burma and Yunnan by the main route through Têng-yüeh can be greatly and permanently increased is by the construction of a railway between Bhamo and Têng-yüeh, and most if not all writers who know the country, agree that such an undertaking would be a profitable one.

When the French line put Yunnan Fu into communication with the sea at Haiphong in the year 1910 it was feared that a diminution in the Burma-Yunnan trade would result at once, because Hsia-kuan is 280 miles from Bhamo and 220 from Yunnan

Fu. These mileages do not represent the true state of the case. The time taken in travelling from the British frontier town to Hsia-kuan is nearly twice as long as that occupied in journeying from the latter centre to the terminus of the line, owing to bad roads across the deep valleys and high dividing water-sheds of the Mekong, Salween and Shweli. Merchants also run greater risks of damage or loss of their goods on a journey between Bhamo and Hsia-kuan than they do between Yunnan Fu and the same place. It was anticipated that the Chinese merchants, who are shrewd enough business men, would soon realise that it was more profitable to supply Central Yunnan with heavy or bulky goods such as cotton yarn and kerosene oil by means of the French railway rather than by way of the overland route from Burma. As a matter of fact these fears have proved groundless up to date, simply because, in the words of the Têng-yüeh Consular Report for 1913, "the freight rates in force over the railway line..... are still so high that the Têng-yüeh merchants are still able to lay down cotton yarn, in spite of the heavy charges for mule hire over the 32 days journey by road from Bhamo, in Yunnan Fu itself at a price which enables it to compete profitably with the same article carried thither by rail direct from the sea."

The position of the overland Burma trade is a very insecure one for the same report states further that, "the French merchants in the south and east of the province are clamouring justifiably for a reduction of the railway freights, and unless something is done to give effect to the agitation in favour of the Bhamo-Têng-yüeh railway organised for some years past by the Liverpool Chamber of Commerce and other influential bodies in the United Kingdom interested in the cotton and piece goods trade with China, the carriage of this important commodity *via* Burma must ere long cease, and our allies will reap the fruits of their energetic commercial competition."

The Bhamo-Têng-yüeh line would have no great constructional difficulties to face; it would traverse fertile and thickly populated plains for the greater part of its length; it would obtain a large passenger traffic; it would bring about a great expansion in the present import and export trade, which, as matters stand, are doomed when the freight charges on the Tongking line are lowered, and further, practically every student of the question who is entitled

to voice an opinion, believes that it would prove a sound, paying concern very soon after its completion.

RAILWAYS.

Early Railway proposals.—The idea of drawing the trade of Western China to Burma is not a new one, for as long ago as 1831 Captain Sprye advocated the opening of a trade route for this purpose. In later years Sprye proposed the construction of a railway line from Rangoon into Siam, and from that country northwards into the Shan States of Keng Tung and Keng Hung. The first survey of a line northwards from Rangoon to Toungoo, (a direction now followed by the main line of the Burma Railways), was the only practical outcome of these proposals. About 1867, when it became known that the Irrawaddy was navigable by steamers as far as Bhamo, the railway question was again revived. Cooper, who was at Batang in 1868, heard from a Chinese trader "of the existence of a trade route from Bathang to Rooemah, a town in the Tibetan province of Zy-yul, situated near the borders of Assam, 20 days' journey distant." In later days there have been others who have proposed to construct railways in this direction, thereby showing a lack of appreciation of the main points at issue, for besides being almost an impossibility on account of the topography of the country to be crossed, it is exceedingly doubtful if such a line would benefit British trade if it were constructed. In 1868 a British Mission under Colonel Sladen proceeded through Burma and penetrated as far as Têng-yüeh, the object being, in the words of General Fytche, "to discover the cause of the cessation of the trade formerly existing by these routes, the exact position held by the Kakhyens, Shans, and Panthays with reference to that traffic, and their disposition, or otherwise, to resuscitate it, also to examine the physical conditions of these routes."

A second mission under Colonel Browne in 1875 was repulsed and attended by the tragedy of the death of G. A. R. Margary, which resulted in the reports of the Grosvenor Mission, and the published opinion of Baber on the Ta-li Fu Bhamo route, which has been responsible for a greater amount of misunderstanding on the subject than any other expression. Baber was not an engineer, and it is a pity that his remarks on this route should have been accepted for so long. In 1881 Colquhoun brought forward a

scheme for a line starting from Moulmein in Lower Burma, running eastwards to Raheng in Siam, and thence north up the Menam valley and through Kengtung and Kenghung to Ssü-mao in Southern Yunnan. This scheme has many very obvious disadvantages, and was rendered unnecessary by the annexation of Upper Burma in 1885. The Upper Burma Railways reached Mandalay in 1889, and as trade at that time had temporarily left the ancient Bhamo-Têng-yüeh route, owing to tribal disorders and consequent danger of travelling, and was then entering Burma by the Kunlon ferry over the Salween into the Shan States, attention was naturally directed in this direction first. In 1895 the construction of the Mandalay-Kunlon railway was ordered, and in 1903 the construction of the line up to Lashio was completed. Already in 1893 the northern extension of the line from Mandalay was opened to Katha, which is the nearest point on the existing railway system in communication all the year round with Bhamo.

The French Line.—The approach of the Burma Railways towards the Yunnan border had not passed unnoticed by the French authorities as may be seen on reference to Prince Henri d'Orleans' writings in 1895, or to Governor-General Doumer's speeches in 1897, and in April 1898 the Chinese Government granted to the French Government, or to a company which the latter might designate, the right to make a railway from the frontier of Tongking to Yunnan Fu. The world already possessed a fairly complete knowledge of the regions of China proper adjoining Indo-China. The magnificent expeditions of Francis Garnier, who, later sacrificed his life in the furtherance of such work, and of many others, had helped towards this end. In 1898 the voluminous report of the Lyons Mission appeared. It contains a number of papers on the trade and industries of Western China by various experts deputed to China by the Lyons Chamber of Commerce.

From December 1897 to July 1898 Leclère, a chief engineer of the Mining Service, toured in Yunnan, Kuei-chou and Kuang-si under orders which he has reproduced as follows: "Il s'agissait de visiter les régions qui seront desservies par le prolongement des voies ferrées de l'Indo-Chine, et d'apprécier l'importance du trafic qui naîtra par l'exploration des richesses minérales." Before this Rocher had shown that Yunnan was exceptionally rich in mineral deposits but it remained for Leclère to give the first detailed accounts of them.

In 1899 the first surveys were made and in spite of the delay caused by the momentous events of 1900, the work was slowly pushed on. In January 1902 the bridge across the Nam-hai between Lao-kai and Ho-kou was completed. From September 1903 to January 1904, Lantenais, Director of the Mining Service of Tong-king, studied the mines and mineral deposits between the frontier and Yunnan Fu and helped in the final decision on the exact route to be followed. In the fever-stricken Nam-ti valley, great trouble was caused by malaria which carried off a large proportion of the total labour force employed on this section. In spite of difficulties of every kind the line was opened to through traffic to Yunnan Fu in the summer of 1910.

The Yunnan Company's scheme.—How far the anticipations of the French diplomatists have been justified is seen from the fact that the railhead of the Burma Railways is still at Lashio. In the autumn of 1908 the "Yunnan Company, Limited," sent an expedition into Yunnan to explore the country, and to reconnoitre for a railway line to connect Kun-lon on the Burmese border with some point on the Upper Yangtze. This expedition was commanded by Major Davies, and included amongst others the skilled geographer Lieutenant Watts-Jones, who later on lost his life in the Boxer rebellion. The results of this survey may be stated in the words of Major Davies: "The total distance from Kunlon to the Yangtze is 1,000 miles. The greater part of the line would traverse exceedingly difficult country, necessitating in places a grade as steep as 1 in 25 and possibly a few short lengths of rack. The total cost of a metre gauge line would be perhaps £15,000,000 to £20,000,000 and the time required for construction would be at least ten years. Though there are great possibilities of future trade the province of Yunnan is, owing to bad communications, at present so little developed that the railway cannot be made as an immediately paying commercial speculation." A recent writer has remarked, "As a purely commercial scheme this railway may be considered as a quixotic venture. It may rather, perhaps, be looked on as a grand Imperial project that, possibly, may be influenced by wide-reaching political issues."

The Brahmo-Têng-yüeh and Têng-yüeh-Ta-li Fu routes.—I do not propose to enter into a discussion on the relative merits of the Kun-lon-Yun Chou-Ta-li Fu route and the Bhamo-Têng-yüeh-Ta-li Fu routes here, but I should like to take this opportunity of stating

that to my own mind, after an extended acquaintance with Yunnan and its trade, there is not the slightest doubt that the latter is the better.

The Bhamo-Têng-yüeh line would approach the T'ien-taung-kuan and Ming-kaun valleys north of Têng-yüeh where iron, silver and lead deposits are being worked by the Chinese. The extension to Ta-li Fu would tap the iron-stone field to the south of Yung-ch'ang Fu, would benefit the Yun-lung Chou salt field, stimulate opium mining south of Hsia-kuan, extend the Ta-li Fu marble business, and render the Yangtze basin and central Yunnan mining fields much easier of access. I have condemned the lignites of the Nan-tien valley as a possible source of fuel for the line, and the nearest coalfield is two stages east of Ta-li Fu.

PART II.

PREVIOUS AUTHORS.

In the account of *Doudart de Lagree's* adventuresome journey through Indo-China in 1866-1868, *B. Joubert* has given some account of the geology of the parts of Yunnan crossed by the expedition, and a few brief notices regarding mineral deposits. (*Voyage d'exploration en Indo-Chine*, Francis Garnier, Paris. 1873).

A Chinese work by *Ou-Ki-Tche*, at one time Viceroy of Yunnan, and *Hukin-sen*, prefect of the city of Tung-Chuan, was written in 1850, entitled "Tien nan kouang tchang tou lou," dealing with the production of metals in Yunnan and the means employed by the Chinese for their extraction and treatment. A translation of this important work into French has been made by Thomas Ko, a Chinese scholar, who was interpreter to the Doudart de Lagree expedition and it appears in the published account of the same. In an introduction to this work Garnier has written,—"Les dernières parties de ce travail contiennent des renseignements administratifs, statistiques et géographiques, très-précis et très minutieux sur la situation métallurgique du Yunnan et j'appelle sur eux toute l'attention des lectures. Ils permettent de se faire une idée exacte des richesses inouïes que renferme cette province et de la prospérité à laquelle elle peut prétendre des qu'elle aura des débouchés suffisants et une administration forte et honnête."¹

E. Rocher, at first a metallurgist and later an official of the Imperial Chinese Customs Service, was sent to Yunnan during the Mahomedan rebellion, in the early seventies. In a work entitled "La Province Chinoise du Yun-nan," he has given some account of the mines of the province then in existence and the methods employed by the Chinese in the mining and the extraction of the different metals.²

Ludvig von Loczy, the geologist attached to Count Szechenyi's expedition through China, made a rapid traverse through Yunnan

¹ *Voyage d'exploration en Indo-Chine*, Vol. 2, pp. 173-264.

² *La Province Chinoise du Yunnan*, par Émile Rocher de l'administration des douanes impériales de Chine, 2 Vols., Paris, 1880.

in 1879. Entering the province to the south-east of A-tun-tzu, he marched down the valley of the Yang-tze to Li-chiang Fu, and thence, still proceeding southwards, to Ta-li Fu. From this city the main westerly route to Bhamo in Upper Burma was crossed. This work is purely geological.¹

Duclos accompanied the Lyons Mission during its tours in various parts of China in the years 1895-1897, and has published a report on the mines and metallurgical industry of Yunnan, Kuei-chou and Ssü-ch'uan.²

Leclère, "Ingénieur en chef des Mines," acting in concert with the mission under Guillemoto, which had for its object the question of the extension of the railways of French Indo-China into China proper, made extensive traverses in the provinces of Yunnan, Kuei-chou and Kuang-si from December 1897 to July 1898 and has given valuable accounts of the geology and mineral resources of the regions he traversed.³

Monod, "Chef adjoint du service géologique de la colonie", also made tours in Yunnan about the same time as Leclère. His results, which differ somewhat from those of the latter geologist are to be found in *Le Bulletin économique de l'Indo-Chine*.⁴

Logan Jack, at one time Government Geologist of Queensland, has published an account of his travels through China to Burma, while escaping from China during the Boxer rising of 1900. Dr. Jack mentions the various mineral deposits he happened to meet with.⁵

Lantenais, "Ingénieur en chef des Mines et Directeur du Service des Mines de l'Indo-Chine", undertook the investigation of the mineral questions connected with the definite choice of a route for the Tongking-Yunnan Fu Railway. His party worked in Yunnan from September 1903 to January 1904, confining themselves entirely to the region between Lao Kai on the Tongking frontier and Yunnan Fu.⁶

¹ *Die wissenschaftlichen Ergebnisse der Reise des Grafen Bela Szechenyi in Ost-Asien.* Vienna, 1892. A Hungarian edition of this work was published in 1890.

² *La Mission Lyonnaise d'exploration commerciale en Chine.* 1895-97. Lyon. 1898, pp. 283-314.

³ *Étude géologique et minière des provinces Chinoises voisines du Tonkin.* *Annales des Mines*, Vol. XX, 1901, pp. 287-492.

⁴ *Contribution à l'étude géologique de la Chine méridionale* *Bull. Econ. Ind. Chine*, Vol. XXXIII, 1898.

⁵ *The Back Blocks of China*, R. Logan Jack, London, 1904.

⁶ *Résultats de la Mission géologique et minière du Yunnan méridional.* *Annales des Mines*, Vol. XI, 1907, pp. 298-503.

Davies, author of the important work, *Yunnan, the link between India and the Yang-tze*, has referred to the mines seen by himself or by members of his parties.¹

Deprat and Mansuy, members of the French Geological Service of Tongking, surveyed large tracts of Eastern Yunnan in the years 1909-11. Their results were published in 1912 as *Mémoires du Service géologique de l'Indo-Chine* :

Vol. 1, Fas. 1. Étude géologique de Yunnan oriental; by Deprat and Mansuy.

Pt. 1. Géologie générale, by Deprat.

„ 2. Atlas, by Deprat.

„ 3. Paléontologie, by Mansuy.

J. Coggin Brown and others. The geological results of my own work have been published by the Geological Survey of India as follows :—

Records, Vol. XLIII (1913), 1. “The Geology of the country between Bhamo and Têng-yüeh.” By J. Coggin Brown.

2. “Petrology of the Volcanic Rocks of the Têng-yüeh area.” By R. C. Burton.

3. “Stratigraphy of the Ordovician and Silurian Beds of Western Yunnan.” By J. Coggin Brown and F. Cowper Reed.

Records Vol. XLIV, “The country around Yunnan Fu.” By J. Coggin Brown.

” ” XLVII, “The Salween and Mekong Valleys.” By J. Coggin Brown.

Accounts of the geology of the country between Ta-li Fu and Yunnan Fu, between Shun-ning Fu and Pu-erh Fu and of the Yunnan course of the Yang-tze have been written but are not published yet.

Only the more important works are given in this list and especially those referring to mines or mineral deposits. Scattered through the published accounts of the journeys of the numerous travellers who have visited Yunnan from the time of Marco Polo

¹ *Yunnan, the link between India and the Yang-tze.* Major H. R. Davies, Cambridge, 1900

onwards, are to be found disconnected references to the geology of the country and its mineral industry. The above list comprises all those who have any claim to expert knowledge or who have written specially on these subjects. Other writers whose works may be consulted for geographical details and for general information include Francis Garnier, Doudart de Lagree, Prince Henry of Orleans, Captain Gill, Ney, Elias Colquhoun, Barber, Bourne, Anderson, Margary, Jack, De Valserre, Amundsen, Macartney, Little, Morrison, Lytton, Francois, Hosie, Ryder, Young, Lord Ronaldshay, Rose, Pichon, Bonin, Vaulxerre, Grillières and others.

CHINESE MINING METHODS.

General remarks on Chinese mining. Mining and metallurgy in China must not be regarded from the standpoint adopted when considering the same arts elsewhere. Separated in their long isolation from the rest of the world the Chinese have had to work out for themselves methods of winning and concentrating ores, of smelting them and of refining the metals so produced. In doing so they have developed a complicated indigenous form of mining administration. Modern native methods in China are those of the ancestral Chinese. At the same time as a race they are skilful prospectors, capable miners and resourceful metallurgists but they are limited by their ignorance of effective means of contending with the natural difficulties which constantly beset the miner. They also lack a knowledge of underground surveying and of the principles of ore deposition.

Chinese theories of ore deposition. All uncommon natural phenomena are believed by the Chinese to be the work of spirits, or "nats" as they would be called in Burma. Temples built in their honour and for their worship adorn prominent mountain peaks; shrines are erected close to hot springs or caves, or even built on the outcrops of lodes. At Bawdwin in Burma, the remains of large Chinese temples are still to be seen close to the outcrop of the Chinaman ore body. The miners themselves believe that metallic ores are the work of the spirits, and each mine usually has its own spiritual patrons. Incense is kept burning at the entrances to levels and shafts and the first two or three sets of timber are usually pasted over with texts and incantations while sacrifices are performed at the appointed intervals.

It is believed that failure to perform these duties would be to risk the spirits' displeasure and would result in the disappearance of the ore body or in accidents to the miners.

I was not permitted underground at the orpiment mines until a fowl had been ceremoniously sacrificed and I have heard from the Chinese themselves that valuable ore deposits cannot be worked in some cases because they happen to occur within the sphere of action of some particular spirit, whom it would be a short-sighted policy to disturb.

Other beliefs are given in the "Tien Nan Kouang Techang," where we are told that the colours of mountains indicate the minerals to be found in them. "When the mountains are clothed with a bluish colour, one may expect to find silver in them. If they contain lodestone their lower beds certainly enclose copper. In fact whatever metallic elements may ordinarily be buried deeply in the ground, a particular sign is always manifested at the surface. This is called "miao" or "guiding sign." The authors further state that it is only by knowledge and long experience that the various forms of the guiding signs can be distinguished. (G., p. 176.)

The Chinese believe in the transmutation of substances. "It would be a great advantage" wrote the authors of the work already quoted, "if some one succeeded in finding the rain which converts itself into gold." It is reported that silver found in mines has vanished sometimes and that it has changed into other substances, and many other similar occurrences are recorded. (G., p. 192.)

It is a mistake to imagine that these and similar theories are entirely puerile, as there is often a stratum of sound common sense underlying the apparent absurdities of the East.

The Chinese in his own country is permitted to explore and prospect as much as he pleases. There are no regulations controlling such operations in Yunnan. The Government used to take no interest in such matters until they got beyond the experimental stage, or, in other words, until they showed any signs of becoming profitable.

The Government has a special interest in copper mines, auriferous deposits, brine wells and salt mines and occasionally in lead, silver, zinc and tin mines and sulphur deposits. From these metals and minerals special revenues are raised, or tribute taken in kind, to supply metals for official purposes like coinage. Other minerals

like coal, ironstone and orpiment belong to a separate class. Lead, silver, zinc and gold deposits commence as a rule in this class and are only transferred to the first when their production becomes important.

When a deposit has been located, if it belongs to group I, the consent of the local authorities is necessary before it can be worked ; in the case of group 2, an arrangement is made with the landowner. This usually takes the form of an obligation to pay him a royalty. A small fee is sometimes imposed by the local magistrate in addition in the form of an annual rent. It is not a recognised tax and is said to go no further than that officer's pocket.

A central office or provincial mining bureau regulates affairs in which the Government has a peculiar interest. This direction is purely fiscal and not technical in any way. Officers are deputed to each important mining centre whose duty it is to see that the various taxes, in money or kind, for which each district is assessed, are forwarded promptly to head-quarters. The prices paid to the miners and smelters is fixed by the bureau. If the district representative can make more than this, he is at liberty to do so, and it is his own perquisite. He is allowed to control the mines in any way he pleases so long as peace is preserved and revenue forthcoming. (Details of actual practice will be found in the second part of this report.) To prove that the above statement is correct and that the central control was a very lax one provided that revenue was regularly collected the following quotations from the works of Baber and Smith are given :—

In referring to certain abuses in South-West China, connected with the production of copper, Mr. Baber remarks "Before the mines can be adequately worked, Yunnan must be peopled, the Lolos must be fairly treated, roads must be constructed, the facilities offered for navigation on the upper Yang-tze must be improved—in short China must be civilised. A thousand years would be too short to allow of such a consummation, unless some force from without should accelerate the impulse." Arthur H. Smith in his work "Chinese Characteristics," adds as a footnote to page 324 after giving the extract from Baber quoted above, "These significant words of the late Mr. Baber have recently received a striking confirmation from a memorial in the *Peking Gazette* of August, 1890, from T'ang Chiung, Director of Mines in Yunnan, who makes a report in regard to the condition of the works and the output.

He states that "a great deal of illicit mining is carried on by the people, and the officials are afraid of the consequences of asserting their rights despotically. A plan has, however, been devised of buying up the copper privately mined by the natives at a low price and thus taking advantage of the extra labour by a measure at once profitable and popular. In this way the memorialist thinks that the mines will work well, and will give no cause for the intrusion of outsiders." The rescript merely orders the Board of Revenue to "take note."

In a postscript memorial the Director informs the Emperor that "ten thousand catties of copper are bought monthly from the illicit workers of the private mines, and that the labourers are not paid wages, but are supplied with oil and rice." In conclusion, he describes the whole state of the mines as "highly satisfactory."

It is not every day that an official of the rank of Governor officially informs an Emperor that the laws of the Empire are constantly and deliberately violated by large numbers of persons with whom the magistrates dare not interfere, but whom, on the other hand, they mollify with oil, rice, and a sum of money sufficient to induce them to part with their stolen copper; and that in consequence of this defiance of the Emperor's and his officials, the condition of the Emperor's mines is "highly satisfactory." No wonder the Board of Revenue was invited to "take note."

A small proportion of the population of Yunnan undoubtedly regards mining as its hereditary occupation and its professional spirit is kept alive by the various guilds and secret societies, which, with the strong ties of family life, unite the fabric of the lower classes of the country. But the great majority of the miners are drawn from the poorest ranks of the agricultural community. They are members of peasant families who cannot make a living on the ancestral farms owing to overcrowding or some other cause, or else they are aborigines drawn from one or other of the numerous mountain tribes.

The lot of the average miner in Yunnan is a most miserable one. He is usually engaged to work for a stated time at a rate of pay barely sufficient to permit him to exist. As a rule he is supplied with a daily ration of rice by his master, who also finds lamps, timber, tools and mining gear. Both master-miner and coolie are alike subject to the tyranny of rapacious money-lenders. There

is a wide gap in Chinese society between the merchants and small landowners on the one hand and the labouring population on the other, and the miner is at the bottom rung of the ladder. His scanty pay, ragged clothes, dilapidated hovel and his lack of all oriental education and culture easily account for this. The master-miners rarely possess capital for any length of time, but there is an ever present demand for metals, which ensures the help of the money-lender, at exorbitant rates of interest. The so-called "Chinese Mining Companies" are often little more than syndicates of capitalists formed for this purpose. Their organization varies on different fields and special rules are framed to meet local circumstances. They are generally formed under the patronage of the local officials who, in the case of deposits of copper, gold, silver and salt, possess practically sovereign powers, and who, in the other cases, act as nominal directors of the company and sometimes invite public subscriptions to raise the loans. The right to sell, purify, smelt and trade in the finished product passes to the company and a fixed price is given to the miner for the ores he wins. Both loan and interest are repayable in kind. The actual mining operations are carried on by the miners themselves under the supervision and direction of their own chief. The ores sold to the company are handed over to the native metallurgists who are controlled in the same way.

Chinese mining. Allowing for the absence of modern methods of artificial ventilation, haulage, drainage and illumination, Chinese mines are comparatively good. Tunnels designed to strike particular lodes are generally driven exceedingly well. Timbering, when it is done at all, betokens expert workmanship. Many simple devices are used to improve ventilation. Illumination is always obtained from molten fat contained in a hemispherical copper vessel, provided with a cotton or pith wick and also with a hook and tilting arrangement. Work is carried on with pick, chisel, crowbar and hammer; the rock faces are often heated and quenched. Gunpowder is rarely used. The workings follow the idiosyncracies of the miner and the peculiarities of the ore-body and the result is often a labyrinth. The Chinese have no system in mining coal, work is continued from the outcrop until falls, water or fire-damp stop it, when the excavation is abandoned and another commenced close at hand. The main roads of the larger mines are high enough to walk along, but in the

actual workings progress is made according to the conditions of the deposit, for no more unproductive material is removed than is absolutely necessary to allow room for a man to squeeze or crawl through. In the salt mines of Ho-ching, I was especially impressed by the height of the roads and the careful way in which pillars of rock salt were left to support the roof. When timbering is not considered necessary a rounded arch-shape is given to the top of the roads and in bad ground the bottom is often rounded too, so that in section the roads are oval-shaped. The number of men employed in one mine depends on circumstances, such as the richness of the deposit, its structure and the demand for the material it supplies. Less than 20 men and boys win all the orpiment which enters Burma from Yunnan, while some of the copper mines find employment for hundreds of men. Every important field draws its labour from a particular district. The Ko-chiu tin-miners come from Lin-an Fu and Lu-nan. I once questioned a large number of Yunnanese coolies returning from the Ruby Mines; with few exceptions these men were natives of Chen-nan Chou. The Bawdwin mines draw their supplies from Hohsa or La-hsa and the surrounding Chinese Shan States and it deserves to be better known what excellent mining coolies these men make, under sympathetic management.

The isolation of China, her immense population and her large internal demand for metals, has resulted in a state of affairs which is unparalleled in any other Eastern country and which has a very important bearing on the future mineral industry. I refer to the fact that the greater proportion of the surface of the land has been thoroughly prospected. It is doubtful if there is a single accessible valley in the Chinese parts of Yunnan which has not been minutely examined for the least traces of copper ores. It is no exaggeration to state that to all intents and purposes, the deposits of metallic ores, with the extraction and uses of which the Chinese are acquainted, or which can be treated successfully by their own methods, are known, recorded and in most instances located. In other words, the mining engineer of the future, be he Chinese or European, will not be concerned with the search for new and unknown deposits of the commoner metals so much as in proving the extension and value of the deep-seated portions of those already worked. The theodolite and diamond drill will be more useful instruments in the future than the prospector's hammer and blowpipe outfit.

SUMMARY OF THE STRATIGRAPHICAL GEOLOGY OF YUNNAN.

On the large map appended to this report I have shown the areas occupied by various groups of members of the geological column, in the regions traversed by myself; accounts of these journeys have already been published or are in preparation. The reader who is desirous of studying the geology of Eastern Yunnan is referred to the beautiful, detailed maps issued with Deprat and Mansuy's memoir by the Geological Department of Tongking. A map published with Loczy's work illustrates the geology of a small strip of country in Western Yunnan, between A-tun-tzu and Ta-li Fu.

I shall now describe briefly the various rock groups:—

(1) Crystalline Rocks.

(1) The term is used here to designate the gneisses, schists and associated crystalline rocks which underlie all the recognised groups and are separated from them by a profound unconformity. These rocks are often intruded by granite and other rocks which are of younger ages, but which it is convenient to consider with them. The following groups of crystalline rocks are known in Yunnan:

- (a) *The frontier ranges of the Irrawaddy-Salween divide.*—A great band of crystalline rocks, upwards of 70 miles wide from east to west in the latitude of Bhamo, forms the hilly country between the Burma-China frontier and the Irrawaddy-Salween dividing range in this region and stretches for unknown distances to the north and south. It may be connected with the Mogok gneiss of the northern Shan States and Ruby Mines district. The typical rock is a banded greyish-white gneiss of medium grain, composed of quartz, felspar and biotite, with garnet as a common accessory mineral. Fine-grained amphibole schists, biotite schists and quartz schists are associated with it. White and greyish crystalline limestones also occur. It is intruded by dykes and large batholithic masses of white and reddish-white granite. In the higher parts of the Irrawaddy-Salween divide, the commonest type of rock is a fine-grained, banded, black and white mica schist occurring with muscovite, quartz and horn-

blende schists and a white porphyritic granite. Further south, where the great range begins to die down, the granites are developed at the expense of the other crystalline rocks, which are normally fine-grained biotite schists and white augen gneisses. Two varieties of granite occur there, the first, a coarse-grained, gneissose kind and the second, a finer sort in thin veins, evidently of later age.

- (b) *The T'sang Shan complex.*—The T'sang Shan range is a high mountain wall rising to elevations of 13,000 feet on the western shores of lake Euh Hai, near Ta-li Fu. Gneisses, schists and crystalline limestones all have a part in its structure and they are intruded by a gneissose granite. The band is not a wide one in this region and its northern limits is not known. (Loczy indicates a small granite boss near Li-chiang Fu, and part of a larger intrusion to the north-east of Wei-hsi T'ing.)
- (b) *The Shun-ning-Yun-chou-Mien-ning crystalline series.*—The crystalline rocks around these towns appear to form part of one band which is in much the same line of strike as the T'sang-shan band, though not directly connected with it on the surface. Around Shun-ning Fu gneisses, schists and granite occur, the former extending for some 10 miles towards the north, almost up to the Mekong. Muscovite and biotite granites were both seen, but the former is commoner. Mica schists, quartz schists and various forms of gneisses occur between Shun-ning Fu and Yun-chou, and also near Mien-ning T'ing where the band is 15 miles wide from east to west.
- (d) *The Yang-tze series.*—Crystalline rocks occur in the Yang-tze valley in the vicinity of its confluence with the Yalung. Specimens from this region were collected by Leclère and examined by Lévy and Lacroix who determined them as diorites with bytownite, passing into amphibolites. The diorite is traversed by veins of microgranulite containing amphibole, black mica, oligoclase and pyrite. In the region of the Ya-lung there is a great massif made up of granulite which near Hui-li Chou is traversed by thick dykes of an ægirine-bearing

nepheline syenite. Accessory minerals include an amphibole of the arfvedsonite family, lepidomelane, sphene, sodalite and cancrinite.

- (e) *Scattered localities in south-eastern Yunnan.*—Crystalline rocks are not widely developed in Eastern Yunnan. In the deep valley of the Red River, and on the borders of the Mêng-tzu basin, mica schists accompanied by cipolins and amphibolites occur. Masses of leptynite and tourmaline-bearing pegmatites are associated with them. In the Ko-chiu neighbourhood these rocks carry cassiterite, and the well-known tin deposits are partly the product of their disintegration.

(2) The Kao-Liang System.

I have given this name to a series of ancient, unfossiliferous, metamorphosed rocks which are common in Western Yunnan, and are generally found between the crystalline rocks and the oldest, undoubted Palæozoic sediments. They consist of phyllites, slates, quartzites and subordinate calcareous horizons and there is invariably a most distinct unconformity between them and the underlying crystallines. A band of rocks belonging to this system and at least 10 miles across crops out just beyond the Mekong on the Têng-yüeh—Ta-li-Fu route. Slates, talc schists and bluish-white quartzites are the prevailing types. To the south the band broadens out and covers a wide extent of broken, deeply dissected country between Shun-ning Fu and Yung-Ch'ang Fu.

These rocks are very similar to the Chaung Magyi rocks of the Northern Shan States, except that they contain calcareous horizons. It is probable that when they come to be examined they will be found to contain beds corresponding both with the Hu-t'o system of Western Shan-si, and perhaps even with the Cambrian in part. This system is well developed in Eastern Yunnan and it may be that the greater amount of metamorphism which rocks of this age must have undergone in the tectonic upheavals of the Mekong ranges has destroyed any traces of fossils they originally contained.

(3) The Cambrian System.

Rocks of this age are only known in Eastern Yunnan, though it is possible that some of the beds classified as Kao-liang in the

western portion may really be Cambrian. According to Deprat they attain a thickness of not less than 2,000 metres between the parallels of Yunnan Fu and the Yang-tze. The series is essentially an arenaceous one and sandstones, slates and schistose shales are of far more frequent occurrence than the rare bands of brecciated and crystalline limestone. In spite of the great amount of disturbance they have undergone and their original variations inseparable from the formation of a detrital deposit in a shallow sea, two divisions have been recognised, *viz.*, the Georgian and Lowest Acadian.

(4) The Ordovician System.

Fossiliferous rocks of this age have been found in three localities in Western Yunnan. They are of little importance as far as the general structure of the country goes or as regards the size of the area they occupy, but they are of great interest from a palæontological point of view. Having read in Loczy's work of the existence of cystidean plates in certain beds near Pu-piao, a village one stage west of Yung-ch'ang Fu, I made a careful examination of the locality and was rewarded by the discovery of a rich fauna; it has been described by Mr. Cowper Reed. At a later period I discovered the fossiliferous localities of Shih-tien and Laméng further to the south, as the map shows.

(a) *The Pu-piao Beds*.—Reddish-yellow, and greyish-green sandy shales with bands of hard, nodular, impure limestone overlain on both east and west by younger Palæozoic limestones and associated rocks. Graptolites and trilobites are the characteristic fossils. Mr. Cowper Reed believes that the fauna, of which 34 distinct species have been recognised, undoubtedly points to a Lower Ordovician age. The graptolites are a typical assemblage from the zone of *Didymograptus Murchisoni*.—The other organisms are allied to or comparable with members of the North European fauna of Ordovician times and scarcely any traces of an American element are apparent. The Pu-piao beds have been correlated therefore with the Llandeilo beds of the British Isles.

(b) *The Shih-tien Beds*.—Red, earthy limestones; massive, light grey limestones; greenish-grey limestones; hardened marls; calcareous mudstones and dark slates. The

beds are faulted against Silurian strata on the west and overlaid by alluvium on the east. The characteristic fossils are beautifully preserved cystideans and trilobites. 46 species have been recognised, many of which are new. According to Mr. Cowper Reed the fauna suggests the Lower Ordovician, especially the Ordovician and cystidean limestones of the Baltic provinces of Russia. Some American Trenton or Chazy affinities are also indicated and at least one of the species has been previously recorded from the Ordovician of China.

- (c) *The La-mêng Beds*.—Hard reddish or purple calcareous slates and mudstones faulted down into rocks of Kao-liang age. The fauna is poor and scanty and only 8 organisms have been recognised. These suggest a Lower Ordovician age.

There is a marked resemblance between the fossils from Western Yunnan and the Ordovician fauna of the Northern Shan States. Both undoubtedly belong to the Lower Ordovician, and both have an European facies and belong to the same division in South-East Asia.

- (d) *Ordovician of Eastern Yunnan*.—Deprat has shown that certain small exposures of greatly metamorphosed rocks, which come to the surface in Eastern Yunnan, belong to the Ordovician. Cowper Reed has pointed out that the Ordovician faunas of Eastern Yunnan and Tongking seem to have a completely different faunistic type from those of Western Yunnan, but the data are insufficient for a satisfactory comparison.

(5) The Silurian System.

(a) *Western Yunnan*.—The Silurian beds are shown with the Ordovician on the map. They have only been recognised in two localities in Western Yunnan, faulted in one case against the Ordovician on Shih-tien hill, and the second further south near Pai-ma. At Shih-tien black fissile slates and greenish-grey or pink flaggy slates yielded a graptolite fauna, belonging, according to Miss Elles, to two horizons. 18 species have been recognised from the zones of *Monograptus Sedgwicki* and *Orthoceras vesiculosus* or *Monograptus gregarius*,

(b) *Eastern Yunnan*.—Deprat has recognised a Silurian horizon to the north of Yunnan Fu, and another in the valley of the Nam-ti, near the Tong-king frontier, where shales with *Spirifer tonkinensis* appear to form a passage between the Gothlandian and the Lower Devonian.

(6) The Devonian System (Older Palæozoic limestones).

On the map the limestones of Devonian and Permo-Carboniferous age are shown together because it is impossible to map them separately without better maps, and also because in the ranges between the Yang-tze and the Salween, they have been so infolded, and in many cases altered, that it is doubtful if they will ever be distinguished separately in the complex where they occur. Their distribution is best appreciated from the map itself.

(a) *Western Yunnan*.—In this region the older Palæozoic limestones are unfossiliferous and the most striking thing about them is their universal brecciation, a character common to the Plateau Limestone of the Northern Shan States. The prevailing rock type is greyish-white or greyish-blue dolomite, crushed and broken to an extraordinary degree and traversed in all directions by minute cracks and veins of secondary carbonates. The surface of the exposed rock is black, very rough and irregular. It is hopeless to attempt to follow up any definite horizons or to establish any divisions in such a formation.

In the Northern Shan States identical rocks cover hundreds of square miles of territory, yet in the whole of the continuous expanse of limestone, extending from Maymyo to the Salween river, with one notable exception, not a single determinable fossil has been recognised, though thousands of outcrops have been minutely examined. The one exception is the remarkable Padaukpyin coral reef which has yielded abundant fossils characteristic of the lower part of the Middle Devonian of Western Europe.

(b) *Eastern Yunnan*.—The presence of strata of Devonian age in Eastern Yunnan has been known since Joubert's account was published, but it remained for Deprat to map and subdivide the rocks in detail and for Mansuy

to describe their fauna. They occupy a great expanse of country between the Triassic geosynclinal in the extreme south-east and the region of the lakes. Pure limestones are said to be exceptional and the rocks are of sandy, marly or shaley-calcareous types. The Lower Devonian, and the Eifelian and Givetian of the middle part of the system, as well as the Frasnian and Fammenian divisions of its upper part are present. They are all very fossiliferous and the forms from the Eastern Yunnanese Eifelian, like the Paudaukpyin fauna of the Northern Shan States, show close affinities with those of the same age from the Rhenish provinces of Europe.

(7) The Permo-Carboniferous System.

(a) *Western Yunnan*.—The fossiliferous Permo-Carboniferous limestones are always found in close association with the older, metamorphosed limestones, which they usually seem to overlie unconformably. They and their associated contemporaneous volcanic rocks occupy a good deal of country in the valleys of the Salween and Mekong and in the Yang-tze valley north of Ta-li Fu. The older limestones tend to give rise to rugged hill-tops covered with screes, or to vertical-sided cañons, while the Permo-Carboniferous build wider valleys and form gentler slopes, through the soil of which their smooth isolated outcrops protrude. The commoner types are dark grey, or greyish-blue, massive limestones with a compact texture, exhibiting bits of shelly fragments and foraminifera in thin sections, whereas the older limestones merely exhibit recrystallized calcite and dolomite. From these rocks I have made large collections of fossils which unfortunately have not as yet been examined by a specialist. Until they have been described it is safer to make no remarks about the probable age of the rocks and their affinities.

Volcanic activity was very prevalent in Yunnan whilst these limestones were being deposited and beds of tuff and ash, intercalated with andesitic, doleritic and basaltic flows, are commonly found amongst them. In some localities they form the greater part of the series.

(b) *Eastern Yunnan*.—The detailed study of the Permo-Carboniferous rocks of Eastern Yunnan has been carried much further than in the case of those of the more westerly parts of the

province, thanks to the brilliant researches of the official geologists of Tongking.

A few exposures of the Dinantian, the lowest division of the Carboniferous have been found by Deprat in the Yang-tze valley north of Yunnan Fu.

The Moscovian or Middle Carboniferous attains an exceptional development and is at least 1,200 metres thick. The lower horizons are sandy, whilst the higher horizons are invariably limestones. Between the two, there is a sandy coal-bearing series with subordinate limestone bands.

During the Uralian, Artinskian and Middle Permian periods, enormous thicknesses of limestone were laid down during a slow submergence of the sea. In appearance they are so much alike that it is quite impossible to distinguish them lithologically, but the beauty and variety of their foraminiferal remains have enabled this to be done by Deprat and his colleagues.

These immense limestone masses have made the scenery of Eastern Yunnan what it is. The folded middle Carboniferous of the regions of the great lakes, owing to the ease with which its sandy horizons are denuded, produces great limestone escarpments on the hillsides or forms the fine lines of the crests. The Uralian and Permian limestones constitute a series some 1,500 metres thick without any other rocks.

At the end of the Middle Permian or perhaps during Upper Permian times a retrogressive movement set in. The land emerged from the sea and denudation vigorously attacked the limestones, removing them more or less completely according to local circumstances.

(8) The Upper Permian or Red Beds Series.

(a) *Western Yunnan*.—The elevation and subsequent denudation of the deposits of the Permo-Carboniferous sea resulted in the formation of a great arenaceous and argillaceous system, not unlike certain facies of the Indian Gondwanas in lithological aspect. A thick conglomerate often separates them from the underlying limestones, and the lower sandstones and shales are characterised by thick beds of rock salt and gypsum. Red and greyish-red sandstones, often in thick bands, reddish-purple and greenish shales, are the commoner types of the series which forms a distinct and very monotonous type of country well seen on the main road between

Ta-li Fu and Yunnan Fu or between the former place and Yung-ch'ang Fu.

(b) *Eastern Yunnan*.—The deposition of the Red Beds commenced here with thick conglomerates and ended with red shales and sandstones containing beds of salt and gypsum. The close of the Permian was marked by wide-spread volcanic eruptions, the andesites and basalts of which attain an extraordinary thickness to the north of Ta-li Fu in the Yang-tze valley and further east also. The effect they have on the scenery cannot be described better than in Deprat's words:—

“Entre la région des lacs et le haut Fleuve Bleue (Yang-tze) les éruptions basiques se multiplient et les énormes coulées de diabases, labradorites et basaltes superposées, pincées dans des plis de vaste amplitude provoquent l'apparition dans la topographie d'énormes croupes arrondies, s'élevant à une altitude très considérable et contrastant vivement avec les formes juxtaposées des calcaires carbonifériens. Les régions occupées par ces roches sont ordinairement très stériles, et le caractère dénudé de ces longues cimes arrondies est vraiment caractéristique.” (De., p. 5).

(9) The Triassic System.

(a) *Western Yunnan*.—A belt of Triassic rocks about 12 miles wide occurs near Yunnan Hsien to the east of Ta-li Fu and appears to strike north into the Yangtze valley where it is at least 30 miles wide. Its further extension to the north beyond this region is not known, and it appears to come to an end a short distance to the south of the Yunnan Hsien area as the map shows. A large collection of fossil remains has been made from the rocks of this basin, the commoner types of which are marls, sandy shales, soft sandstones and occasional limestone horizons. The fauna is sure to prove a most interesting one, but as the collection has not been examined, it is impossible for me to fix the horizons of the various beds themselves. If a guess may be hazarded, the general appearance of the fossils seems to indicate that both middle and upper Trias and perhaps Rhætic beds occur. The Triassic coals of the basin are of considerable economic importance.

Another Triassic basin was found between Meng Chu and Ssü-mao in South-western Yunnan but as only one rapid traverse was made across it, its limits are not known. Middle Trias horizons seem to be represented in it.

(b) It seems probable that Triassic strata were deposited over a considerable portion of Eastern Yunnan and that they were generally removed during the severe erosion which took place in Pliocene times. The small areas which are found now owe their preservation to faulting. They occur in the extreme south-east of the province. The transgression of the Triassic sea covered a surface exposed to long erosion during the Upper Permian, and at first formed lagoon-like expanses in which the lowest deposits of the system were laid down as alternations of beds containing terrestrial plant remains with others characterised by marine forms. The three great divisions of the Trias are represented and well marked off from each other by distinguishing faunas. As a rule they are said to be very folded and even inverted. The uppermost beds of the Lower Trias have a littoral facies and the passage from the Werfen to the Mesotrias is a progressive one. The Mesotriassic forms collected by Loczy at Tehung-tien in the far north-west in Ssü-ch'uan are practically identical with those from the extreme south-east of Yunnan, which tends to prove that similar conditions prevailed over a very extended area. These conditions entirely changed with the passage into the Upper Trias, the deepening of the sea attained its maximum, pelagic conditions set in, and an invasion of cephalopods, marked by the especial development of ammonites of the *Trachyceratidæ* family, took place during the Noric and the Carnic. A definite uplift commenced in the upper Noric period and sandstones containing coal-seams were formed. Similar conditions of a continental character probably existed during the Rhætic at any rate over Eastern Yunnan.

My own view is that the transgression of the Triassic sea was a slow and progressive one from east to west in Yunnan and that the continental conditions indicated by the great deposits of the Red Beds series persisted in Western Yunnan to a much later period of time than they did in the east of the province. According to La Touche the Trias is entirely absent from the northern Shan States, which nevertheless contain Rhætic and Jurassic deposits of a marine character with rich faunas. Now Jurassic strata are known to occur in Ssü-ch'uan, but no trace of them remains in Yunnan, if they ever existed at all. These facts seem to justify my assumption that the Red Beds series, though confined to the Upper Permian in Eastern Yunnan may be of true Permo-Triassic age further west, and that the marine conditions which set in in

Eastern Yunnan in the Trias did not reach the northern Shan States until Rhætic and Jurassic times, when the Triassic deposits of the eastern area were already undergoing uplift and denudation.

The Jurassic system is unknown in Yunnan and the Cretaceous has never been recognised anywhere in China proper.

The Pliocene (Nan Tien Series).

With the Upper Trias marine sedimentation ceased and the only known deposits of a later age are the fluvio-lacustrine or lacustrine beds of late Tertiary times. Deposition is still in progress in some of the lake basins so it is sometimes impossible to separate the older deposits from the newer. The beds themselves consist of sands, sand-rock, clays, pebble beds and conglomerates. Bands of lignite are also known to occur in places.

These continental conditions, unimportant from the stratigraphical point of view, witnessed epoch-making changes of another kind. At a period which belongs to the early Himalayan phase, Yunnan and the Shan States were involved in far-reaching folding movements which have been worked out in detail by Deprat. Overthrusting was common and the Yangtze region in the neighbourhood of the great bend, was pushed forward on to the Yunnanese area further south. A long period of peneplanation followed, the Himalayan folds were planed away by denudation and eventually, probably towards the end of Pliocene times, great faults cut across the region. These caused most of the depressions, which during the subsequent period of stability gave rise to the lakes wherein the late Tertiary fresh-water deposits accumulated, while at the same time the river valleys became choked with thick sandy deposits. The final phase, a very decided uplift, is responsible for much of the present topography. It also drained many of the lake basins and installed the minor features of the existing hydrographic systems.

PART III.

COAL.

Coals of three distinct geological ages are found in Yunnan, belonging to the late Tertiary, Trias or Rhætic and Carboniferous periods respectively.

Tertiary Lignite.

Lake basins filled with lacustrine and fluvio-lacustrine deposits of late Pliocene and recent ages abound throughout Yunnan. To these deposits I have given the name "Nan Tien Series." Bands of impure carbonaceous shale and lignite very often occur in them and are mined sometimes for local domestic purposes.

A typical occurrence is that of the Nan Tien plain (lat. $24^{\circ}49'$, long. $98^{\circ}22'$) which extends for some 15 miles down the Nam Ti valley between Bhamo and Têng-yüeh. Well-marked terraces, about 80 or 90 feet high, border the plain on both sides of the river and are deeply dissected where small tributary streams cross them. Sections of the deposits show them to be made of beds of sand loosely held together, pebble beds which, being slightly cemented, have the appearance of conglomerates, silts, and bluish clays with bands of carbonaceous shale containing fragments of lignite. About half a mile to the east of Nan Tien itself, a band of black carbonaceous shale, about 12 inches thick, crops out in a high terrace of these Tertiary deposits, composed of hard blue clays and white and yellowish sands. In the next valley to the north there are two outcrops of the same sort of material both about 15 inches thick and separated by 20 feet of yellowish sands. The outcrop of one of the bands can be traced for 300 yards. The material composing the seams is not a true coal, but a carbonaceous shale which has been formed by the addition of much vegetable matter to the mud of a lake or slowly flowing river. It decomposes very easily and goes to pieces when dried, or on exposure to the air for any length of time. In places it is purer, and masses of lignite, evidently formed from fragments of driftwood, occur in it.

Similar deposits are found in the Kan-ngai valley (lat. $24^{\circ} 47'$ long. $98^{\circ} 8'$), in the Lo-po-sü-ch'uan where beds of lignite-bearing shales are worked near Lai-fu, in the Yung-chang Fu plain, and indeed in most of the old lake basins of Yunnan. As the material has no economic value, except possibly a very small local one, it is not proposed to describe the separate occurrences.

In Eastern Yunnan precisely similar deposits occur. They were noticed originally by Leclère and Monod and later by Lantenois who pointed out that the lignites could not be sold in Tongking and only possessed a local interest.

The lacustrine deposits of the Têng-yüeh valley, (lat. $25^{\circ} 0'$ long. $98^{\circ} 30'$), contain beds of peat, which is black, somewhat compressed and has remains of thin roots and stalks of plants preserved in it. Under the alluvial soil and loam, thin layers of yellowish grey clay are usually found, underlain by lighter sandy beds made up almost entirely of small grains of clear quartz with a few milky grains of felspar. Under the sandy beds there is often a layer of black peat up to 4 feet in thickness. During the winter the peat is dug out and sold for burning in stoves. It has been formed in much the same way as the lignites, though it is considerably younger.

Brown lignitic coals, containing a high percentage of moisture are found in various parts of the Northern Shan States of Burma in small basins filled with late Tertiary silts, occupying the valleys of the streams that rise among the hills surrounding Loi Ling, the loftiest mountain in the States. Sometimes the seams attain a considerable thickness, one in the Lashio field being 30 feet thick. Attempts have been made to use some of these lignites but up to the present time they have not been successful. They are mentioned here because of their similarity of composition, occurrence and formation with the lignites of Yunnan.

Analyses of late Tertiary lignites. A number of assays of lignites from various localities are tabulated below:—

Locality.	Mois- ture.	Volatile matter.	Fixed carbon.	Ash.	
Nan Tien (1) . .	16.5	39.05	22.58	21.87	Does not coke, ash dark brown.
Nan Tien (2) . .	15.22	28.94	18.08	37.76	Does not coke, ash dark brown.
Tang chi (Eastern Yunnan).	33.05	34.07	24.27	8.61	Does not coke, ash light brown.
Northern Shan States	16.78	35.72	32.85	13.28	Mean of 29 assays from various localities, quoted by La Touche.
Mi-la-ti (1) . .	17.20	29.20	38.20	38.20	Lignites from Eastern Yunnan. Analyses from Lantenais, none of these yields coke. Tang-chi is a French analysis of same material, shown in line 3. The specimen from P o u c h a o - p a, (No. 5), gave a calorific power of 3,400 calories (Berthier's method).
Mi-la-ti (2) . .	16.20	31.30	32.50	20.00	
Pou-chao-pa (1) . .	30.25	31.15	26.00	12.60	
" " " (2) . .	45.00		24.00	31.00	
" " " (3) . .	12.75	34.25	16.50	36.50	
" " " (4) . .	12.00	34.00	17.50	36.50	
" " " (5) . .	19.33	24.00	50.23	6.44	
Tang-chi . .	16.00	52.00	27.00	5.00	

True Coal.

In the report of the Lyons Mission both Rocher and Duclos draw attention to the occurrence of coal in Yunnan; but Leclère established the existence of two coal-bearing horizons of Palæozoic and Mesozoic age respectively, though his estimates of the quantities available have proved to be very much exaggerated in the light of more recent knowledge. These horizons he regarded as belonging to (1) beds of Carboniferous age below the Productus Limestone, and (2) the Rhætic. Lantenais attributed the deposits he examined to (1) the Carboniferous, and (2) the Trias or Rhætic. Deprat has recently worked out the stratigraphy of the coal-bearing rocks and has concluded that coal occurs in the following beds in Yunnan :—

Upper Trias . . .	Upper Noric sandstones.
Middle Trias . . .	Sandstones with <i>Myophoria inæquicostata</i> .
Lower middle Trias . .	Coarse sandstones.
Lower Trias . . .	Psammites
Moscovian . . .	{ Limestones with <i>Spirifer mosquensis</i> .
	{ Upper red sandstones.

According to this writer the only horizons capable of yielding continuous seams of good quality belong to the Noric, Werfen and Moscovian. The other horizons contain irregular seams of very impure coal containing large quantities of pyrites. I have examined occurrences of Palæozoic and Mesozoic coals in Yunnan. The Yunnan Hsien-Yangtze valley field undoubtedly belongs to the latter division, but until my fossil collections have been determined, I cannot state whether these coals are of Triassic or Rhætic age. With the exception of the Yunnan Hsien field all the Mesozoic coals of Yunnan are confined to the eastern and south-eastern parts of the province, a region which I did not examine. The following notes concerning them are taken from French sources as indicated.

Upper Triassic Coal.

The coal-seams of the Upper Trias are intercalated in the Noric sandstones which terminate the system in Ni-ou-ke occurrence. Yunnan. Leclère, Lantenois and Deprat¹ have described the occurrence at Ni-ou-ke, 10 kilometres east-south-east of A-mi Chou (lat. 23° 41' : long. 103° 17'). Leclère attributed a Rhætic age to the deposits, which Lantenois admits is possible. Deprat states that they are of Noric age, at the top of the Yunnanese Trias. Four seams occur with a total thickness of 3 metres; the principal seam which is worked is 1.2 metres thick but it contains marly bands.

The following analyses of coal from Ni-ou-ke are given by Lantenois :—

No.	Moisture.	Volatile matter.	Ash.	Calorific value.
1	3.0	33.50	4.10	...
2	8.00	25.00	17.00	...
3	7.04	...	18.42	4.740
4	8.80	21.00	18.38	4.690
5	...	30.00	6.00	...
6	4.00	32.00	13.00	5.350

¹ Le., pp. 353-354; La., pp. 395-396; De., p. 244.

Leclère gives a composition of from 30-35 per cent. of volatile matter and about 6 per cent. of ash. The coal is said to burn with a bright flame and to yield a light friable coke. Its worst

defect is the large proportion of fines. It is used in distilleries at Mêng-tzū.

In the neighbourhood of Ta-yao-chai, a village some 25 miles east-north-east of A-mi chai, two coal seams were found by Deprat.¹ The first occurs half way between Yang-tsi-kiou and Ta-chai, dipping to the north-west and forming part of a syncline of Upper Trias rocks. The seam is about a metre thick; the outcrop coal is weathered and pulverulent, but is probably better in depth.

The other seam crops out on the road between Ta-yao-chai and Chong-chai and is associated with coarse sandstones containing plant remains belonging to the Upper Noric. The seam dips north-east and the coal visible at the surface is dull. It may be better deeper down.

If these deposits eventually prove valuable, it must be remembered that they are two stages away from the railway and consequently can only be utilised in Yunnan itself owing to the cost of transport.

Middle Triassic Coal.

The coals of the middle Trias are of little economic importance. They are disseminated in sandstones and shales and are generally very admixed with clay and shaly material.

Lantenais² regarded the Tse-sou seams as Upper Trias or Rhætic, but Deprat³ has shown that they are associated with the sandstone containing *Myophoria inæquicostata* which are correlated with the St. Cassian horizon or the upper portion of the Middle Trias.

Two seams, each about 1 metre thick, separated by a band of coarse sandstone, are found between Ya-ma-chai and Tse-sou. Both authorities state that the coal is of very mediocre quality. The locality is about 15 miles east-north-east of A-mi chai.

Near Sin-tien, Deprat noticed a coal seam about 1·20 metres thick in the coarse sandstones at the base of the middle Trias. The coal is of very poor quality and mixed with much clayey material. Were this not so, its distance of over 60 kilometres from the railway at A-mi chou prohibits its transport.

¹ De., p. 245.

² La., p. 395.

³ De., p. 243.

Lower Triassic Coal.

The Lower Triassic beds of the region between Mi-lê Hsien (lat. $24^{\circ} 23'$: long. $103^{\circ} 27'$) and Tou-tzu, forty five miles further to the north-east, contain some of the best coal deposits in Yunnan whether regarded from the point of view of quality or quantity. It is unfortunate that their minimum distance of 2 or 3 days' journey from the railway prevents their scientific exploitation.

These deposits were first examined by Connillon who came to the conclusion that only one seam, varying in thickness from 0.8 to 1.5 metres, existed. But Coal-seams between Tou-tzu and Mi-lê.

Deprat has shown that this is not the case; thus between Je-shui-tang and Ho-kiou there are four. The seams are actively exploited by the Chinese and the coal is made into coke for domestic purposes.

In every occurrence this coal is bright, generally pure, free from shaly partings and only contains a little pyrites. It is not as fragmentary as the Moscovian coals are and many of the Chinese mines yield large-sized material.

The following analyses are from various sources:—

District.	Locality.	Moisture.	Volatile matter.	Ash.	Calorific value.	Authority.
Mi-lê	Mi-si-sao	0.80	12.00	32.20	..	Connillon and Lantenois.
	Lao-song-chiu	1.00	13.00	20.50	5,924	Do.
	I-wi-chao	0.70	19.70	14.00	6,098	Do.
	Tsin-si-kou (1)	1.40	26.20	14.50	..	Do.
Between Mi-lê and Tou-tza.	Tsin-si-kou (2)	1.00	24.30	12.40	5,964	Do.
	Pu-chiao	0.50	22.60	9.00	..	Do.
	Sai-kao	2.35	12.70	71.30	1,226	Do.
Tou-tza	Tou-tza	1.00	17.40	8.00	6,470	Do.
Tou-tza	Tou-tza	0.95	16.75	7.50	8,010	Monod.
Tou-tza	Tou-tza	1.30	15.00	10.00	7,500	Leclère.
Mi-lê	Near Jeshui-tang		37.00	9.54	..	Do.

These analyses are compared by Lantenois with those of the Hongay briquette and the Miike coal of Japan.

Locality.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	
Hongay briquette	2.20	15.20	6.00	6,682	
Miike (Japan)	1.20	37.10	12.70	5,838	

These coals furnish an excellent coke especially suited for metallurgical operations. The Tou-tza coal is very friable but the other localities yield compact solid material. The calorific power is generally high.

Mesozoic Coal in Central Yunnan.

Leclère in 1898 seems to have been the first European to learn of the existence of coal in central Yunnan. Writing of the rocks met with near Yunnan-i he states "They probably reach to the Rhætic horizon, for at Mu-pang-pu coal outcrops are worked, from which an ashy coal is won, which is nevertheless made use of as far as Yunnan-i" (Le., p. 397).

I visited the area in November 1908 and again in June 1909.

In the hills to the south of Miao-tsway a village 2 or 3 miles south of Yunnan-i (lat. $25^{\circ} 26'$: long. $100^{\circ} 42'$), three coal-seams are found, each three or four feet in thickness and separated by bands of hard yellow and yellowish-white sandstone. Interbedded with these are layers of soft, greyish-white, sandy shales. Fossils were collected from certain marly horizons in the vicinity, but until they have been determined, the exact age of the seams themselves cannot be stated, but they probably belong to either the Trias or the Rhætic. The outcrop coal is won by the Chinese by means of shallow drifts and incline shafts. The seams strike $N 15^{\circ}-20^{\circ}E$ and have a high dip in a south-easterly direction. Samples from two of the seams gave the following results on assay :—

Locality.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	
Miao-tsway (1)	2.03	8.10	83.28	6.59	Does not coke.
Miao-tsway (2)	1.52	9.00	79.13	10.35	Sinters slightly.

I was informed on Chinese authority that coal was mined to the south of Miao-tsway, and in February 1910, I was able to confirm the truth of my information. Near the village of Li-kang-ch'ang, towards the southern end of the Mi-tu plain, and approximately ten miles in a south-westerly direction from Miao-tsway,

Extension of the
Yunnan Haïen field.

as the crow flies, two or three seams crop out at the edge of the valley. The seams are from 5 to 10 feet thick, but owing to the mines being abandoned and the locality overgrown with thick grass, I was unable to make any detailed examination. Whether the coal-bearing rocks stretch much further south is not known. Towards the north-east in the direction of Miao-tsway, there is said to be a group of Chinese coal mines at Mu-ku-lang, 3 miles from Li-kang-ch'ang.

On the northern side of the Yunnan Hsien plain, the coal horizons crop out, being hidden under the lacustrine deposits of the plain in the intervening area. Coal is mined on the south-western slopes of peak 6,950, which lies to the east-north-east of the city, but which does not form a very conspicuous land-mark, as the surrounding plain has an elevation of more than 6,000 feet. The thick soil-cap hides most of the rocks in the vicinity of the mines but the exposures that are visible exhibit the same soft yellow sandstones and marls as those found at Miao-tsway, ten miles to the south-east on the other side of the plain. The strike is north and south and the dip high towards the east. A few fragmentary plant remains were collected in weathered shale on an old mine heap. There appear to be two seams and in the vicinity of the village of Ta-ho-tsun, lines of old workings run in an almost due north and south direction for over a mile. The only rocks visible are a few isolated exposures of soft yellow sandstones. Outcrop material from the two seams assayed as follows:—

Locality.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	
Ta-ho-tsun (1)	8.26	14.85	54.98	21.90	Sinters slightly
Ta-ho-tsun (2)	4.27	9.88	58.98	26.87	Sinters slightly.

The coal-bearing rocks are again met with near Tong-ch'uan, a small village one stage to the north of Yunnan Hsien. The road to the mines leaves the village of Lung-yu-tsun, which is situated at the eastern edge of the Pin-ch'uan Chou plain (lat. 25° 44'; long. 100° 33') and proceeds up the valley of a small tributary stream to the east, for about a mile. At first the Permo-Carboni-

ferous volcanic rocks are passed and the then dark indurated shales, followed by coarse gritty sandstones. These strike north-east to south-west and dip south-east at 42°. Unfortunately a thick soil-cap hides the rocks near the mines, but the horizon is probably the same as the Yunnan Hsien one, from which it is separated by a distance of about 14 miles as the crow flies. An assay of the weathered coal from this locality gave the following result :—

Locality.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	
Tong-ch'uan . .	3.33	7.51	72.06	17.10	Sinters slightly.

Coal-seams are also found on the western side of the Pin-ch'uan Chou valley. From the small walled city of Chou, Coal-seams to the west of Pin-ch'uan Chou. that name a road leads in a north-westerly direction to Kan-tien at the edge of the plain. At this place coarse sandstones and shales strike north 30° west and dip in a north-easterly direction at 55°. Two miles further west there are exposures of grey sandstones separated by layers of grey micaceous shale. Coal is mined about two miles to the south-west of Kan-tien, which lies at the foot of a spur running out from a well-marked ridge. Very few rocks are visible near the workings, but the type of strata found further away is lithologically identical with the coal-bearing horizon of Tong-ch'uan and Yunnan Hsien.

An assay of a sample from a heap lying near the mouth of an old working gave the following results :—

Locality.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	
Kan-tien . .	2.01	8.55	71.14	18.03	Sinters slightly.

Mesozoic Coal of the Yangtze Valley.

Yunnan Hsien is in the valley of the Red River, but very close to the divide between it and the Yangtze. The northern extension of the Yunnan Hsien field is situated within the drainage system of the Yangtze. On the northern bank of the river coal is extensively worked about Chiu-ya-p'ing Hsien (lat., 26° 38' : long.

101°13') and Ma-ch'ang (lat. 26° 35': long. 101° 27'). The former place is about 80 miles in a straight line to the north-east of Pin-ch'uan Chou and, although the greater part of the intervening region has still to be examined, there is some reason for supposing that it forms part of the Triassic basin of Central Yunnan, and if this should prove to be the case, there is a probability of coal being found in it.

According to Joubert, (G., Vol. II, p. 164). the early French fathers seem to have been the first Europeans to recognise the existence of coal in the Yunnan course of the Yangtze. Garnier's mission visited a mine near Ma-ch'ang in 1868 and noticed the seams cropping out on the river banks. One seam was more than seven feet thick and the coal of good quality though friable. Owing to this property it was all coked locally before being sold. (G., Vol. I, p. 505 and Vol. II, p. 165).

In 1898 the region was traversed by Leclère from whose writings I have translated the following notes. The country between the north and south course of the Yangtze and its tributary the Yalung which flows in a similar direction¹ is not composed of the ancient Sinian rocks as Loczy's map indicates, but is occupied by Mesozoic formations which continue and complete those of Central Yunnan. Superposed in the Ta-li Fu region on Palæozoic formations, Triassic, Rhætic and Liassic sediments follow one another towards the east. The ancient shore runs north and south on both banks of the Yangtze for distances that are still unknown and encloses coal deposits of great value.

The most easterly outcrops of Rhætic coal are found about 10 kilometres down stream from Ma-ch'ang. The principal seam exploited in the vicinity is at the base of a hill called Ke-ti-pin, 5 kilometres from Ma-ch'ang. The same easterly-dipping horizon is exploited at a great number of places on the right bank of the river, for example near Ta-pin-ch'ang. From the roof of a mine below Ma-ch'ang, in a seam 6 feet thick, dipping at 40° to the east, plant remains were collected which Zeiller correlated with those from the Rhætic of Tongking. The gallery of this mine penetrated more than 800 feet into the seam in a horizontal plane and from it about five tons of coal were won daily. The small coal was coked on the spot. The larger coal was sold a day's journey away at about 4½ francs per ton, but the local inhabitants are given to

¹ The distance indicated is about 90 miles across in a straight line. J. C. B.

using outcrop coal which they gather themselves. A French missionary stationed in the vicinity could obtain good coal by sending out his servants for a day to collect it.

Between Ma-ch'ang and Chiu-ya-p'ing Hsien coal outcrops are found on the lower slopes of the hills, overlain by limestones. The little mines made by the people of Sin-kai and Chiu-ya-p'ing Hsien yield the best coal that Leclère met with. Coal is the only fuel used in the district though wood is by no means scarce. It burns with a brilliant flame and very little smoke in the open grates of the houses. Leclère gives the following assays of these coals:—

Locality.	Moisture.	Volatilo matter.	Fixed carbon.	Ash.	Calorific power.
Tai-pin-ch'ang (1) .	2.6	32.4	59.0	6.0	7,854
Tai-pin-ch'ang (2) .	...	36.6	...	4.56	...
Near Sin-kai* .	9.6	39.1	47.3	4.0	...
Near Sin-kai† .	...	18.25	...	3.6	8,389

Personal Observations.

I made a rapid traverse across this region in May 1909, but I fell ill in Chiu-ya-p'ing Hsien and was not able to add very much to Leclère's work. He is certainly correct in assuming the existence of a wide Mesozoic basin between the eastern part of the Yangtze bend and the Yalung. On the west the Red Beds are followed by the Trias between Ta-lu and Wei-sha, and on the east they overlap on to the igneous rocks of the Permo-Carboniferous in the neighbourhood of Hsin-chuang. Thus the basin has an approximate width of 50 miles, measured in a straight line from east to west. We have no knowledge as to its northern limit but it would appear to reach the valley of the Li-t'ang river in Ssü-ch'uan.

The first coal outcrops are found near Chiu-ya-p'ing Hsien, some 18 miles from the western edge of the basin. This town lies at an elevation of 4,200 feet in the narrow valley of a small tributary flowing from the north-west to join the Hsien-chuang Ho, a tributary of the Yangtze on its north bank. Coal seams crop out on

* Outcrop material.

† Picked up from road where it had fallen in transport. *Le.*, pp. 386-389.

both slopes of the valley and the tops of the ridges are capped with limestones which I believe are either Upper Triassic or Rhætic in age.

I visited a small mine at Pa-sha-shan, in the steep range which borders the Chiu-ya-p'ing Hsien valley on the west. The mine is about two miles to the north-west of the town at an elevation of 6,000 feet above the sea. Further to the north-north-west the ridge rises to an elevation of 10,000 feet above the sea. After crossing one limestone band the track ascends across red shales topped by steep limestone crags. The coal-seams crop out in a series of coarse, soft, grey sandstones, banded with variegated and yellowish shales containing carbonaceous layers. On the occasion of my visit only one seam was being worked, from three steep inclines which descended in a northerly direction from the outcrop. About 16 men were employed and the coal was drawn out to the surface in iron-shod sledges. The monthly output was about 20 tons and was sold locally for domestic purposes. The coal itself was hard, bright and of excellent appearance. There are other mines further south along the line of outcrop.

Owing to the similarity of geological structure on both sides of the valley, it was anticipated that coal would be found to the west of the town. This proved to be the case and there are several outcrops in the first stage between Chiu-ya-p'ing Hsien and Hsin-kai.

Coal to the west of Chiu-ya-p'ing Hsien. Leaving the valley the red shales are followed by limestones dipping to the east-north-east at 20°, which give place to the coal-bearing, yellowish shales and sandstones again, capped by the upper limestones. Coal was mined at We-pan-tsun and Ta-pin-t'zu, while near the village of Ta-wa which is built on the eastern slope of the ridge bounding the Chiu-ya-p'ing Hsien valley, I found indications of outcrops.

Coming down the valley from Ta-wa to Hsin-kai, I noticed many abandoned drifts in the sandstones. I had no time to visit the active workings, to the west of the village, but the coal which is burnt locally is of fine quality, being hard, bright and well cleated. It does not soil the fingers when handled.

Ma-ch'ang is only six or seven miles to the east of Hsin-kai, and is situated on the northern bank of the Yangtze. The coal-bearing series continues all the way, but I did not see any outcrops.

Coal in the Ma-ch'ang vicinity.

of seams or workings. The mines which Leclère described were abandoned but active exploitation was being carried on at Mo-so-ho four miles further east. On both banks of the Yangtze below Ma-ch'ang for several miles there was a well-marked coal horizon. Most of the northern workings seemed to be abandoned, but mining was being prosecuted on the south bank of the river. The coal from this neighbourhood is the best I ever saw in Yunnan and it yields a coke of very good appearance.

Coal in the Hui-li Chou District.

Hui-li Chou (lat. $26^{\circ} 39'$: long. $102^{\circ} 15'$) is in the province of Ssu-ch'uan, but it is advisable to mention the occurrence of coal in the district. It is worked at several places between the city and the Yunnan frontier.

Between the villages of Ta-chiao and Chieh-tien-po, a few miles south of Hui-li Chou, soft yellowish sandstones, marls and shales interbedded with coarse grits, contain thin coal-seams.

In the vicinity of Ho-kou, 30 miles south-south-west of Hui-li Chou, I saw heaps of powdery coal outside some of the houses and was informed that it came from the hills to the west.

Near Lu-shui-ho, 10 miles south of Ho-kou, a powdery coal is mixed with clay and formed into cakes for burning in stoves.

These coals are probably of Mesozoic age, but they are crushed and of very poor quality.

Leclère mentions the existence of good coal to the south of Hui-li Chou, and it is also known to occur between the same city and Tung-ch'uan Fu (lat. $26^{\circ} 24'$: long. $103^{\circ} 10'$). The coals reported from various localities between Tung-ch'uan Fu and the Yangtze are perhaps of Carboniferous age. Regarding them Joubert has written (G., Vol. II, p. 165):—

“Between Tung-ch'uan and Sui Fu occurrences of coal and anthracite are very abundant, every day we passed them on our journey. Mines are so numerous that we only cite the principal ones: Chao-tong, Chin-yuan, Ma-tsao-ku, Pu-erh-tou, Ta-kuan, etc. The Ke-lu mine, on the bank of the Lao-ya-tan river, three *li* below Teai-hiang-kuan, furnishes a coal of excellent quality. These coals are generally dry. The coal from the red sandstones and shales is of superior quality to that found near the Devonian limestone; with the former coke can be made; the latter crumbles to powder

easily, and ought to be converted into briquettes before being used."

Mesozoic Coal in Southern Yunnan.

Joubert records the existence of coal near Na-kou-li between Ssu-mao T'ing (lat. $22^{\circ} 50'$: long. $101^{\circ} 0'$) and Pu-erh Fu (lat. $23^{\circ} 5'$: long. $101^{\circ} 5'$): "Near Ssu-mao, between Na-ko-li and Ho-boung there is an occurrence of anthracite which is mined for use in the salt works of Ho-boung. The seams strike north and south and are numerous, close together, but of slight thickness; in a space of 38 feet 5 seams could be counted. The thickness of the seams varies between one inch and one foot approximately. The length of the occurrence is not even roughly known, but the coal is extracted at two places, six kilometres apart" (G., Vol. II, p. 164).

Joubert visited this region in 1867. I passed through it in 1910 but found no trace of any workings. I was not able to identify the village of Ho-boung which may have been destroyed in the rebellion.

Carboniferous Coal.

The Moscovian coals of Yunnan are confined to the eastern parts of the province and have been studied by various French engineers. I have visited most of the important localities and have recorded the following observations.

Excellent exposures of the Middle Carboniferous horizons are found at Eurl-kai, a small coal-mining village situated a few miles to the north-west of K'ungyang Chou (lat. $24^{\circ} 40'$: long. $102^{\circ} 32'$). For part of the way, lacustrine deposits of the lake basin of Yunnan Fu hide all outcrops, until sandy yellow shales are found, followed by limestone bands. The following section is seen at the mines.

	Thickness.
(d) Dolomitic limestone	?
(c) Limestone with <i>Euomphalus</i>	10 feet.
(b) Sandstone with coal-seams	40 "
(a) Reddish limestone	?

According to Deprat, coal-mining was started here in 1901. When Lantenois visited it in 1903 two seams were being worked though he was able to recognise a total of four (La., p. 392). I only saw two of these as the outcrops of the others were buried by falls. Each seam was about 4 feet thick, and separated by bands

of sandstone and shale. Deprat states that there are at least four seams varying in thickness from $3\frac{1}{2}$ to $5\frac{1}{2}$ feet. The strike at the mines is north-east to south-west and the dip at a low angle to the south-east. In the hills to the north-west, I found horizon (c) again and I believe the coal-bearing stratum is to be found there also. Most of the coal is coked on the spot and then sold in Yunnan Fu for domestic purposes. It is transported to the capital by junks. At the time of my visit to Yunnan Fu it was proposed to use the coke in the Imperial Mint and Arsenal. Analyses of the coal are given in the following tables:—

Locality.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Calorific power.	Remarks.	Authority.
Eurl-kai (1) . . .	0.60 2	13.00	..	14.00	6,300	..	Lantenols.
" (2) . . .	1.00	16.00	..	14.70	5,040	..	"
" (3) . . .	0.80	14.70	..	16.00	6,200	..	"
" (4) . . .	1.20	14.30	..	13.00	6,240	..	"
" (5) . . .	1.10	15.40	..	13.00	..	..	"
" (6) . . .	1.25	14.75	..	16.00	..	..	"
" (7) . . .	1.00	19.25	..	11.50	..	..	"
" (8) . . .	1.17	15.67	62.13	21.03	..	cakes but not very strongly.	Coggin Brown.

The Middle Carboniferous succession found at Eurl-kai is exposed

Middle Carboniferous of Hai-kou and Hsin-tsun. on both sides of the narrow valley of the P'u-tu Ho, which drains lake K'un-yang. For over a mile between Hai-kou and Hsin-tsun, the coal-bearing sandstones can be seen high above the river and they are doubtless prolonged further to the south-east in the direction of the lake. Near Hsin-tsun I found the following sequence, the rocks themselves being nearly horizontal:—

	Thickness
(e) Thick bluish-grey limestone . . .	?
(d) Limestone with <i>Chaetetes</i> . . .	?
(c) Limestone with <i>Euomphalus</i> . . .	?
(b) Sandstones with coal-seams . . .	30-40 feet
(a) Limestone . . .	?

Only a few abandoned pits along the outcrop were noticed. As Deprat remarks, this locality offers considerable inducement for modern methods of exploitation.

A few miles to the north of Yunnan Fu (lat. $25^{\circ}0'$: long. $102^{\circ}45'$), the Uralian limestones which occur in the immediate vicinity of the city, give place to strata of Moscovian age, the coal-bearing series already described being represented as follows:—

- (c) White fossiliferous limestone.
- (b) Sandstones and shales with thin coal-seams.
- (a) Sandy limestone.

Two pits had been sunk on a thin coal seam and a boiler was in course of erection to supply steam to a small pump with which the Chinese authorities proposed to unwater the mines. An assay of the coal gave the following results:—

Locality.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	
Yen-tzu-shao . .	.77	15.88	52.85	30.50	Cakes but not very strongly.

The horizon is perhaps the same as the one found by Leclère (Le., p. 362), at Kwei-long-chuan at the extreme north of the Yunnan Fu plain, near the celebrated pagoda of He-long-tan, where an almost flat seam about three feet thick crops out. It was used locally in lime kilns and assayed as follows:—

Locality.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Calorific power.	Authority.
He-long-tan . .	1.3	11.0	65.7	22.0	6,734	Leclère.

The Middle Carboniferous is well developed in the mountain ranges running north from the vicinity of the Middle Carboniferous of Si-yang and Ta-wa-tzu. Yang-tsung lake (lat. $24^{\circ}55'$: long. $103^{\circ}5'$). The northern part of the valley of the small stream which joins the Pei-ta Ho at Yi-liang Hsien, is bounded on the west by a high and precipitous escarpment, in which rocks are exposed ranging from the Middle Carboniferous to Upper Permian-Carboniferous horizons. As is the case in other localities, the Middle Carboniferous coal-bearing horizon occurs and the seams which it contains are exploited by Chinese methods, most of

the material being converted into coke which is sent to Yunnan Fu. At Si-yang, the northernmost point where coal is worked, the following series is exposed :—

- (h) Hard greyish limestones.
- (g) Bluish dolomitic limestone.
- (f) Greyish sandy shales with coal-seams.
- (e) Yellowish dolomitic limestone.
- (d) Greenish shales.
- (c) Thin limestone bands.
- (b) Red shales.
- (a) Limestone.

There are two coal-seams, the upper of which is five feet and the lower between seven and eight feet thick. Both are worked in the usual haphazard Chinese fashion.

I made another ascent of the scarp from Yang-kai to Ta-wa-tzu (elevation 7,300 feet above the sea), in the neighbourhood of Eul-long-si-chou. Here there are two seams in the same succession of limestones and shales. The strike is north 35° east and the dip westerly at 44°. The scarp itself runs north 20° east, and old coal workings extend along it for miles, confirming the continuity of the seams themselves. According to Deprat, the seams are continuous over a distance of 5 kilometres, the coal is less broken up than in the other occurrences and it yields a good coke for metallurgical purposes. The seams are free from bands of shale. These localities supply, I believe, coal which is used on the French railway. It is carried to the line on pack ponies. The following analyses are available :—

Locality.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Calorific power.	Remarks.	Authority.
Eul-long (1) . .	1.00	14.60	..	28.60	5,140	..	Lantenais.
Eul-long (2) . .	1.00	14.40	..	11.00	..	..	..
Eul-long (3) . .	.85	15.90	75.03	8.22	..	cakes strongly, gives a light coke	Coggin Brown
Si-yang (1) (upper seam).	1.93	15.23	74.32	8.52	..	cakes	..
Si-yang (2) (lower seam).	19.73	27.02	45.95	7.01	..	sinters slightly.	..

The Middle Carboniferous is well developed in a synclinal fold bounded on the east by the fault which forms the western shores of Lake Yang-tsung, and on the west, according to Deprat, by another fault which brings it into contact with the Cambrian. At various places in this district thin coal-seams occur in the sandstones and shales over the limestones. I saw several old pits, but they are little more than prospects. The following analysis is given by Lantenois :—

Locality.	Moisture.	Volatilo matter.	Fixed carbon.	Ash.	Authority
Tsi-tien . . .	1.70	20.55	...	22.50	Lantenois.

According to Deprat (De., p. 240), the coals of this locality are friable and full of pyrites. They have been tried on the French railway which crosses the region and were given up as useless. The coal is only good enough for lime- or brick-kilns.

Other Coal Mines.

The following occurrences of coal are reported on the authority of the French geologists, in order to complete this account. I have not seen them myself.

T'ung-hai Hsien (lat. $24^{\circ}6'$: long. $102^{\circ}48'$) has an elevation of 6,200 feet and is 65 miles south of Yunnan Fu, in a direct line. There are three groups of workings at the following places :—

- (a) Ta-che-shan.
- (b) Hsiao-pa and Lu-shui-tang.
- (c) Lu-chuang.

A single seam varying in thickness from seven or eight inches to a little over three feet is interbedded in a series of sandy shales from 30 to 60 feet thick, intercalated in thick limestones. Exploitation seems to have been carried on for a long time as the pits are very deep. The coal is used in brick-kilns, lime-kilns and forges where the impure iron from the Hsi-o mines is worked up into horse-shoes, nails, etc. The latter are sent through Southern Yunnan, as far as Ssu-mao T'ing which has an important trade with Hsi-o, and to the Laos. Lantenois made his observations in the winter

of 1903-04. Deprat visited the mines in 1909-10 and reported that conditions had not changed in the meantime (De., p. 239). Lantenois gives the following analysis of the coal:—

Locality.	Moisture.	Volatile matter.	Ash.	Authority.
Hsiao-pa . . .	0.90	14.30	24.25	Lantenois.

Pai-ching is a small village about five miles north of Hsin-hsing Chou (lat. $24^{\circ}20'$; long. $102^{\circ}35'$). Near the Prospects at Pai-ching, village a coal-seam occurs in a series of shales overlain by limestone. An insignificant amount of prospecting has been carried on about the outcrop and has revealed a thin seam of altered coal with an apparent thickness of 1 foot 3 inches. The interest of this occurrence lies in the fact that it may represent the southern extension of the coal-seams found at Eurl-kai, 18-20 miles away to the north as the crow flies. Lantenois has given the following assays (La., pp. 390-395):

Locality.	Moisture	Volatile matter.	Ash.	Authority.
Pai-chung (1) . .	1.00	20.60	20.75	Lantenois.
Pai-chung (2) . .	1.75	17.00	38.00	„

At the extreme south-eastern corner of Lake Yang-tsung, Deprat reports a coal occurrence in certain red Moscovian sandstones which are lower down in the succession than the coal-bearing rocks already described. The coal is mined by the Chinese and has a high percentage of ash. It is interbedded with bands of shale and carries an unusual amount of pyrites. This coal is almost completely useless and can only be used in lime burning. A similar occurrence is recorded between Sin-kai and Chêng-ch'iang, and here, if anything, the coal is of worse quality than the preceding. A number of the same kind of seams are situated in the mountains bordering the western side of Lake Chêng-ch'iang. They possess no interest and were not described (De., p. 241).

It seems certain that the impure coals of this particular horizon will never be of any economic importance for there is little chance of their improving in depth.

Chinese Methods of Coal-mining.

Chinese coal-mining methods as practised in Yunnan are of the most primitive description. Starting from the outcrops of the seams, levels or incline shafts are driven down on the coal, according to its inclination. If the ground is hard no timbering is done, but if it should be bad, which is usually the case, the working is timbered with sets and the roof and side kept up by lagging, though the minimum amount of timbering is put in. The coal is broken down with small picks and carried out to the surface either in baskets or on small sledges with iron-shod runners usually drawn by boys. As a rule no side galleries are made, and the single drive is carried on until ventilation becomes bad enough to make work impossible, when the miner abandons the pit and commences another hole in a favourable position on the outcrop. Naked oil lamps, something after the fashion of an Indian *chiragh* are used and explosions of fire-damp are not unknown. Whenever a fatal accident of any kind occurs the working is at once closed and a new one started. Accidents are believed to be due to the malevolence of the earth spirits when their abodes are disturbed. Water is not a serious trouble in any of the Yunnanese coal workings which I have seen. Owing to the softness of the outcrop coal, such workings are quickly and cheaply driven and the outcrops of seams in localities where this primitive form of mining is freely carried on, are marked by lines of old holes and small dumps which sometimes extend for miles.

Coal is not often burnt in its natural state in Yunnan. On most fields the material is coked or where the nature of the fuel does not permit of this being done, it is powdered and mixed into a paste with clay; from this plastic material, thin circular cakes are moulded by hand, dried in the sun and sold for domestic consumption. When burnt in hearths they smoulder slowly away leaving a mass of glowing ash which retains its heat for a long time. This is the method employed with the non-coking Triassic coals.

The Yunnanese coke oven consists of a circular hole dug in the ground and about 10 feet in diameter, with a flat bottom and sloping sides. In the centre of the bottom there is a circular hole communicating with a narrow flue. The bottom of the oven is lined with large stones and is usually constructed on a hill-side to allow of the flue being entered and cleaned. Large lumps of coal are arranged in the bottom around the air-hole together with a little

wood to start the combustion. Small passages are left as channel for the gases and air. Smaller coal is then gradually piled on top and the outer hemisphere covered with earth, which is broken through when the operation is complete. Small air holes are left at the junction of the inner and upper chambers. In this way a hard coke of excellent appearance is produced, though it tends to be somewhat tumid when very bituminous coal is used.

Owing to the practice of mining outcrop material and of allowing shaly partings to be mixed with the coal, as this does not interfere with the preparation of the sun-dried briquettes already referred to, it is almost impossible to obtain fair samples from stock heaps at the mines. In mining no selective care of any kind is exercised and inclusions of shale and dirt bands, or pieces of the floor and roof of a working are matters of no consequence at all.

General Remarks on Yunnan Coals.

Deprat has summarized the views of his colleagues on the Triassic coals of Yunnan as follows (De., p. 245):—

“The Triassic coals have very variable qualities: those of the Werfen are the best coals in Yunnan and yield an excellent, solid, dense coke. The seams are of great extent; these coals are not so friable as those of the Moscovian or of the Upper Trias. The Middle Trias coal is always deceptive and was formed under conditions which produced irregular beds distributed in the sandstones. Those of the Noric on the contrary appear better; the Ni-ou-ke coal is typical; they produce a friable coke, but they are rich in volatile matter and are gassy.”

The analyses of the Mesozoic coals of the Yunnan Hsien basin show that this material is lower in volatile matter than the Triassic coals of Eastern Yunnan and with one exception they can only be classed as poor material. Yet I am inclined to regard this poverty in volatile matter as a result of superficial atmospheric action on outcrop material rather than a quality inherent in the coal itself. Further north, in the Yangtze valley, the coal of the Ma-ch'ang and Chiu-ya-p'ing Hsien districts, which is probably of the same age as that of the Yunnan Hsien basin, possesses, as Leclère's analyses show, a higher percentage of volatile matter and a better calorific power, than any of the other Triassic coals of Yunnan. It also gives an excellent coke. The seams of this region are mined deeper than those further south. The high ash

percentage in both Triassic and Carboniferous coal is partly due to the Chinese practice already commented on. I feel sure that the ash contents could be very considerably reduced by proper mining methods.

My analyses of the Moscovian coals as well as those given by the French writers, show that they are semi-bituminous and yield a coke of good quality. They are probably better than the Mesozoic coals for steam-raising purposes.

The friability of most of the Yunnan coals is a serious defect and I agree with Lantenois that it is probably the result of general geological conditions and not likely to improve with depth (La., p. 403). However, the question cannot be settled definitely until deeper mining is introduced.

Future of Coal-mining in Yunnan.

I regard Leclère's estimates of the amount of coal available in Yunnan as vague conjectures and nothing more. We know that a great deal of the country which he assumes to be coal-bearing is built up of older formations in which coal does not occur. At the present time it is impossible to arrive at any figures which are likely to approach the truth, and until the fields are bored, the most that can be said safely is that they are likely to contain large quantities of coal.

Yunnan coal has a future before it in the local market for domestic purposes and metallurgical operations, but owing to the land-locked position of the province, forming as it does the western hinterland of continental China, I do not think that it will ever attain much sale beyond the frontiers.

The greatest consumption will doubtless be as fuel for the railways of the province. Indeed the Moscovian coal of the Si-yang district is already so employed. Some of the French writers have concluded that Yunnan coal will find a market in Tongking and even in more distant regions, but it seems to me that it will need a hard struggle to capture markets now supplied by Japanese and to some extent by Indian and Australian coal. It must not be forgotten that the coal production of Japan now exceeds that of India, and that production in Japan has always exceeded home requirements, so that a large tonnage is available for export and sale at fairly cheap rates.

The briquettes used on the railways in Indo-China are made at Hongay from mixtures of the rather poor coal found there and the richer Miike coal of Japan. Lantenois states (La., p. 404) that even the better qualities of Japanese coal are bituminous and pyritous and consequently encrust and burn the fire-grates and boiler tubes. The Yunnanese coals are better in this respect, and the interesting suggestion is made that mixtures of gaseous coal like that from the Ni-ou-ke field in south-eastern Yunnan, and the low grade coals of Tongking should be made for burning in steam-boat and locomotive boilers. This suggestion is based on the success with which such mixtures of small or even dust coal have been used as locomotive fuel on some of the railways in France. Such mixtures consist of $\frac{1}{4}$ of poor material averaging 9 or 10 per cent. of volatile matter with $\frac{3}{4}$ of rich material averaging 30 or 35 per cent. of volatile matter. Conditions are not very different in Tongking where the local coal contains 8 to 10 per cent. of volatile matter and the Miike coal or the Ni-ou-ke coal of Yunnan contains 30 to 35 per cent. of volatile matter particularly rich in hydrocarbons.

I do not know whether such experiments have been undertaken. Their success, if the composition of the coals as given holds equally good for bulk, depends largely on the costs of transportation.

IRON.

Iron ores are well distributed throughout Yunnan and although the mining and treatment of iron ores has never attained the importance of copper metallurgy, the industry is a settled and well established one and regularly supplies the demands of the Province in cast iron, wrought iron and steel.

The "Tien-nan-kouang-tchang" enumerates fourteen ironstone mines, presumably working about 1850, but it is doubtful whether any of them can be identified with modern mines (G., II, p. 232).

Joubert states that the richest deposits exploited at the period when he travelled in Yunnan were situated at Kang-tchong-pa and Lang-pong-li. I am not able to identify these localities. He also mentions the fact that iron minerals occur at Siao-tsao-pa, on the banks of the Kokui river. (G., II, p. 159).

Rocher writes that ironstone mines are more numerous than any others in Yunnan and that they appear to have been operated by the aborigines before the advent of the Chinese into the country.

Iron ore is said to be so common in Yunnan that Rocher was unaware of a single district which did not possess one or more deposits, but as mine-owners sought the centres of population and the rivers, and as the cost of transport diminished profits, only the richest deposits were worked. This writer gives no list of occurrences to confirm his somewhat optimistic views, but he describes at length the processes used by the Chinese in obtaining iron from its ores, in preparing wrought iron from crude cast iron, in the manufacture of steel and in the preparation of the large cast iron pans so much used in China for domestic purposes. The towns of Lu-fêng Hsien (lat. $25^{\circ}7'$: long. $102^{\circ}7'$), and Lu-nan Chou (lat. $24^{\circ}46'$: long. $102^{\circ}24'$), are mentioned as important centres for the production of refined iron manufactures, while the indigenous steel business was said to be at its best in Lao-lu-kuan, a village between Hsin-hsing Chou and Hsi-o Hsien (lat. $24^{\circ}10'$: long. $102^{\circ}24'$). (R., pp. 195-218).

According to Leclère, in a mineralised country like Yunnan, iron ore deposits are naturally very frequent. They are exploited in regions where forests still exist, for the manufacture of both iron and steel. In the north-eastern part of the neighbouring province of Kuei-chou, the nodules from the infra-Lias are used for local smelting purposes. Again, considerable quantities of large concretions of carbonate of iron are found in certain coal-bearing horizons below the Lower Productus Limestone. It is held that with very few exceptions these deposits cannot contribute towards the mineral development of the province. Leclère visited the iron-producing regions about Yi-mên Hsien (lat. $24^{\circ}39'$: long. $102^{\circ}10'$), and Hsi-o Hsien. In the case of the former his notes refer mainly to the methods of Chinese smelting. In the case of the latter, the mine was visited later by Lantenois, and a summary of his report is given below. (Le., p. 438).

Lantenois learnt from the magistrate in Hsi-o Hsien that at least a dozen centres of ironstone mining and smelting existed within two or three stages of that town and that the total annual production of metallic iron was not less than 1,500 metric tons. The most important place is Chan-héou, one stage to the south-west of the town. The steel-producing centre of Lao-lou-kouan is not far distant. With the exception of the Hsi-o Hsien district this authority met with no ironstone mines in the course of his travels in Eastern Yunnan. On the road between Pe-tchen and

Tien-pao and not far from the Tsi-tien coal mine, he found pieces of iron ore from the strata immediately below the Carboniferous limestone. He describes the following mines:—

The mines supplying the iron for the manufacture of steel at Lao-lou-kouan. Lao-lou-kouan are situated on the road between that place and Chan-héou. The deposit consists of small pockets of ore which are fairly numerous in the Carboniferous quartzites. The deposit has only been scratched about the outcrop and the production is very small; perhaps about 100 metric tons per annum. The ore is sold at a price corresponding to 2 francs per ton. (La., pp. 416-417).

This deposit is in the form of nodular masses with a rough stratification in a Carboniferous limestone formation which is about 100 metres thick and interbedded with quartzites. The ore is won in a methodical and correct manner and is sold at about 4 francs per metric ton at the smelters. Each miner produces about $3\frac{1}{2}$ cwts. per day and is paid a wage corresponding to $\frac{1}{2}$ franc per day. Lantenois describes briefly the processes used in the manufacture of iron and steel. The latter is sold at a price corresponding to 300 francs per metric ton, and the finished bar iron is worth 170 francs per metric ton at Hsi-o Hsien, a price not very different from the ordinary European value of the metal. The production from this region is sent in part to T'ung-hai Hsien where it is worked up into all kinds of domestic articles to be sold over the regions of Southern Yunnan bordering the French Laos. The other part goes south to Mêng-tzū Hsien, K'ai-hua Fu and as far as Upper Tongking, or even to the north towards Yunnan Fu, though the main supply for the capital seems to come from the Yi-mén Hsien region. (La., pp. 416-417).

Deprat did not observe any interesting iron ore mines in the regions which he traversed. He records the occurrence of a siderite vein of no economic importance near Ta-li-tang and the existence of limonite nodules in lacustrine deposits at Mi-leu. (De., p. 246).

Personal Observations.

Iron ores have a wide distribution in Yunnan and while none of the deposits appear to be extensive, or in any way comparable with, say, the extended occurrences in the crystalline rocks of the Indian Peninsula, yet, it is believed that nearly all the large centres

of population have their somewhat small requirements supplied by mines in the same regions. Where any unusual demand has arisen as in the case of the cast iron pans used in the brine-boiling industry, there is generally a mine, blast furnace and foundry not very far away. As examples, the needs of Yung-ch'ang Fu are met from the mines at P'ing-tai in the Ta-tien-pa valley, two stages to the east of the city. Têng-yüeh is partly supplied from the T'ien-t'ang-kuan, a valley north of the city. Yunnan Fu derives its supplies from the Yi-men Hsien region, the cities of south-eastern Yunnan from the Hsi-o Hsien district and so on.

The hemispherical cast iron pans of Yunnan are much appreciated by the Chinese everywhere and can be found in any bazaar in Upper Burma. Again, the thousands of mules engaged in the trans-frontier trade and in the Shan States every winter are always shod with Yunnan-made shoes and nails and every caravan carries a large stock of these excellent articles about with it.

The Iron Industry of the T'ien-t'ang-kuan.

T'ien-t'ang-kuan is one of the smaller divisions of the Têng-yüeh district. Its principal village is Ying-pan-kai, 37 miles almost due north of Têng-yüeh T'ing. The district is bounded on the north by unadministered territory inhabited by Lisu tribes; on the east by Ming-kuang; on the west by Ku-yung and on the south by Hsi-lien. The valley contains a small but fertile plain about 8 miles long and 1 or 1½ miles broad, which has been formed by the Hsiao-pa Ho, the eastern branch of the headwaters of the Shweli river. The plain has an average elevation of about 6,000 feet above the level of the sea.

The Lung Chiang or Shweli as it is known to the Burmese, divides into two streams near Ch'ü-ch'ih, 17 miles north-east of Têng-yüeh. The main stream proceeds in a north-north-easterly direction, but the other takes a more westerly course as far as Kung-kai, 22 miles north of Têng-yüeh. Here it divides into two streams, the No-lo Ho, which continues in a north-north-easterly direction, almost parallel to the main river, and forms the Ming-kuang valley; and the Hsiao-pa Ho, which flows from the north-north-west and forms the valley known to the Chinese as the T'ien-t'ang-kuan. The two districts are separated by a single range of mountains which attain elevations of from 8,000 to 10,000 feet above the sea, but the two streams are only from 8 to 10 miles

apart as the crow flies. These mountains bordering the T'ien-t'ang-kuan on the east, meet with the western boundary range at the head of the valley, in the peak Chien-shan, which is over 11,000 feet high, and about 15 miles north of Ying-pan-kai and quite close to the Burma-China border. I have given these geographical details because I have noticed that recent writers have only a hazy idea of the correct position of these valleys.

From Têng-yüeh to Ying-pan-kai, the centre of the iron industry of T'ien-t'ang-kuan, is a journey of three days. The first stage is at Ma-chan-kai, a large village 14 miles to the north of the city. The second stage is at the market village of Ku-tung-kai, 23 miles from Têng-yüeh. Two roads leave this place, one in a north-easterly direction to the Ming-kuang, and the other in a north-north-westerly direction to the T'ien-t'ang-kuan. The latter road is nearly level and keeps to the spurs of the hills for 7 or 8 miles and then crosses the paddy lands of the plain. Continuing along this, still in a northerly direction, Ying-pan-kai is reached at 34 miles and Ma-li-pa at 37 miles from Têng-yüeh.

The village of Wan-yao, where iron bowls and pottery are made, is in the Hsi-lien district and about half-way between Ma-chan-kai and Ku-tung-kai ; it lies some $\frac{3}{4}$ mile to the west of the main northern route.

On my journey to the T'ien-t'ang-kuan, I found that the volcanic rocks already noticed by Anderson and Loczy, have a considerable extension to the north and I was fortunate in discovering a number of ancient cones from which these rocks have come. A full account of them has already been given. (C. B. I). The T'ien-t'ang-kuan plain consists of alluvium, underlain by lacustrine deposits of late Tertiary age. These are made up of yellow friable sandstones, clays with carbonaceous bands. In the eastern boundary range, granite is the principal rock. Two groups of hot springs were found near the village of A-hsin-kai, which is half way between Ku-tung-kai and Ying-pan-kai. One group is just below the spur on which the village is built, and the other 600 yards to the south-west. Old deposits of sinter exist near. The water from the spring is intensely hot and the hand cannot be placed in it.

The mines lie at the head of a small valley formed by a tributary of the Hsiao-pa Ho, which is entered to the east, just to the north of Ying-pan-kai. The

valley itself runs almost due east and west, the mines being from $3\frac{1}{2}$ to 4 miles from the village and over 800 feet above it. Ying-pan-kai itself is nearly 6,000 feet above sea-level. The main road from Têng-yüeh to Ying-pan-kai is not in bad condition as far as Yunnan roads go, but between the latter place and the mines there is only a mule-track of the roughest description, the route following *bunds* between the paddy fields in the valley, and traversing the slopes of the mountain sides higher up. Pack animals can be taken either way if loaded lightly.

The mines themselves are located in a small hollow, which seems to have been brought into existence partly by the numerous quarries and open-cast workings of the past. Owing to a thick soil-cap and the vegetation which covers the surface, beyond the fact that the mines are merely drives made into a large ore-body, practically nothing could be learned of the geology of the vicinity during the short time at my disposal. A fine-grained pinkish granite crops out in a few places between the village and the mines, which, in general appearance greatly resembles the Ming-kuang granite.

There were six drives but only one was being worked at the time of my visit. It descended steeply into the ground for about 30 feet when it turned in a southerly direction with only a slight slope. The inclined part of the working had been made with steps to facilitate ascent and descent. The first 25 feet were of necessity well timbered, for the ground was very bad, beyond this the timbering was not good and the whole place was in a very unsafe condition. The roof was a very bad one and small stones kept coming down during my inspection. The working was dry and there was no lack of ventilation. The working was entirely in ore, the material of which was easily brought down with the pick, a form of mining much appreciated by the Chinese. I traced the outcrop of the ore-body on the surface for 60 feet and it could probably have been found much further had I been given time to have a few trenches made. It strikes a few degrees east of north and is from 10 to 15 feet wide. It consists almost entirely of a hard, massive, brown hematite. The exposed portions are somewhat oxidised and weathered on the outside. Amongst my specimens I recognised specular iron ore and small quantities of magnetite, both massive and crystalline. The hard specimens of the ore are of good appearance. It is impossible to compute the limits of the amount of ore available here without some preliminary

development, neither have I any remarks to offer as to the nature of the occurrence. All I can say is there was sufficient material visible to last the Chinese many years at the then rate of consumption.

It would be expected that the miners would prefer to win rich ore from the outcropping portion, rather than to mine it. But the tools at their disposal are of poor quality and gunpowder does not appear to be used locally, so that it is really easier to make small tunnels in soft portions of the ore-body, than to attempt to smash up the hard portion which weathering has left on the outcrop. The ore is carried out to the surface in baskets and there broken up and hand-sorted, only the purer pieces are kept and second grade material is rejected. It is then loaded into small mule panniers and taken down to the smelters at Ying-pan-kai or Ma-li-pa. Mining is only carried on during the dry season; in the rains the workers returns to their farms for the paddy season. The mines are said to have been worked at intervals for a number of years, but only about 15 or 20 men were employed when I was there in 1909. The headman of the gang of miners is financed by the company, which takes all the ore produced and allows 40 cash for every 100 catties of ore handed over. This works out at the small sum of Rs. 1-5 per ton. A charge equal to $1\frac{1}{2}$ annas is made for transporting one mule load of ore from the mines to the smelter.

There were three blast furnaces at Ying-pan-kai and five at Ma-li-pa. Those at the former place had
 Smelting.
 been built on the mountain slopes across the valley, but at Ma-li-pa they were in the village itself.

The furnace is of massive stone-work, the back and sides forming a rough semi-circle. It is lined with a refractory white clay. It differs essentially from the high blast furnace that I have seen used in other parts of Yunnan as it is only seven or eight feet high at the back, and the side walls five feet in thickness. The shaft is broader at the top than at the bottom. The blast is let in by a tuyer which enters the lower portion of the back wall and has a slight downward direction towards the hearth. The blower is seven or eight feet long and one and a half feet in diameter. It is worked by a turbine. The tapping-hole is situated on the right-hand side, and is also used as the slag outlet before the hearth gets full of molten metal. In front of the furnace is a paved stone incline which slopes up to within two feet of the top of the front wall. At the bottom of this is a stone-paved tank through which

water is allowed to flow and which is used to quench the hot material raked down the slope at the end of the operation. Just above the place where the long sloping hearth meets the front wall, there are three upright rectangular holes, which serve as places where long iron rods can be introduced by means of which the charcoal and ore are kept from clogging. The brick wall on the right-hand side of these holes is removable, and is pulled down at the end of a blow to enable the hot charge to be raked down into the water-tank.

I regard this furnace as partly calciner and partly blast furnace, as it is only intended to serve in the preliminary treatment of the ores, which always undergo another reduction before metal is obtained which can be used. For example, in the manufacture of castings like bowls, the impure material from the first furnace is always reduced with charcoal in a smaller and more powerful blast furnace before metal pure enough for the purpose is obtained. The first furnace reduces part of the ore to the metallic state and prepares the remainder for a subsequent treatment.

Charcoal and ore are added from time to time during the 24 hours which the smelting takes. Two grades of material are yielded by the furnace—(1) flat cakes of crude iron, which are obtained by allowing the molten metal to flow from the tap-hole over the ground; (2) material raked out of front and quenched in water. This appears to consist of finely divided metallic iron mixed with a good deal of charcoal and roasted ore; it is eventually worked up into horse-shoes, nails, knives, ploughshares, etc.

The working up by charcoal is done in a forge the bed of which is oval and some three feet long by two feet broad. It is erected on solid brickwork raised to a convenient height from the ground. The blower used is a small one, and is placed with a slight downward tilt to the hearth of the forge, being slightly raised above the level of the hearth so that the tuyer, which enters through a raised brickwork wall at the back, has a downward turn given to it. The blower in this case is worked by hand. A small anvil is placed near.

One furnace produces from 130 to 260 lbs. of iron in 24 hours. A tax of three annas is demanded by the Provincial Government for every 100 catties of iron produced. Charcoal is very plentiful and cheap locally. Sometimes in the course of smelting small "blooms" of steel are formed in the furnace, but this is quite accidental and is not looked upon as desirable, as the "blooms" collect around the tuyer and so stop the blast. The local workers appeared

to be unable to make any use of these small and hard lumps of steel.

There are furnaces and moulds for the manufacture of cast iron pans at Ma-li-pa and Wan-yao. The furnace used is a small, round-bottomed, tilting blast furnace from four to five feet high. The shaft is broader at the top than at the bottom. It is made of thick clay-work and strongly bound with iron bands. The narrow part is fitted into a large, round-bottomed, cast iron pan, about $1\frac{1}{2}$ to 2 feet in diameter, the joint being luted with clay. This forms the hearth. The ground in front and underneath is cut away for 6 or 8 inches, except for two small projecting pieces on each side, on which the hemispherical iron bottom of the furnace rests, and which serve as pivots on which the whole arrangement can be tilted slightly. When upright it also rests for support on the somewhat higher ground at the back. The tuyer enters the back wall just above the junction of the clay and iron work, and it has a slight downward inclination towards the hearth. It is connected to the blower by means of a long bamboo pipe, so that the heat from the molten metal may not injure the woodwork of the blower. The tapping-hole is slightly below the level of the tuyer, but is cut in the front of the furnace. A rough bamboo shed covers the furnace and blower and serves as a protection for the workmen in bad weather.

The blowing machine is of the type which is commonly used throughout Western China for most metallurgical operations. It is made from the trunk of a large tree, which is cut lengthwise before having the interior removed, in order to leave as perfect a hollow cylinder as possible. The two pieces are arranged to fit together and the joints are made airtight by the application of clay. The length varies greatly for different purposes, but for the supply of air to a small crucible furnace like the one under description, a blower $4\frac{1}{2}$ or 5 feet long is used. For the large copper furnaces seen in some parts of the country very much larger machines are made. The piston is made of wood and is caused to fit exactly by having the rims of the circular piece at its head packed with feathers. The ends of the blower are made from circular pieces of wood and are movable. One is pierced with a circular hole for the reception of the piston rod, and both have a couple of small rectangular holes which are fitted with valves of soft leather on the inside. On one side of the cylinder two larger holes are cut and

over them is placed a rectangular box which acts as an air chamber. The tube conveying air to the tuyer is $1\frac{1}{2}$ or 2 inches in diameter and passes out from the other side of the air box.

The blower is worked by a water turbine, which is similar in action to the vertical axled water wheels so commonly used in the Himalayas for the supply of power to corn mills. The motion is conveyed to the piston rod of the blower by means of a wooden crank and long wooden cross-piece.

The furnace having been filled with a mixture of crude cast iron and charcoal, laid on a charcoal bed in the hearth, is ignited. The blast is then turned on by opening a small wooden slide which allows a strong current of water to fall on to the turbine. A great heat is soon developed, flames of carbon monoxide issue from the top of the crucible, the metal is liquified and collects in the hearth. The tapping-hole is closed by means of a removable clay plug, operated with a long iron rod. As soon as the master smelter considers that sufficient metal has collected in the hearth, the blast is turned off, the blower disconnected, the plug removed from the tapping-hole, the slag carefully cleaned away by means of a long iron bar, and the whole furnace bodily tilted, with the help of a long wooden beam which rests on the ground, and when lifted catches on a projection from the back of the furnace.

This movement throws the furnace sufficiently out of the vertical to cause the molten iron to flow from the tapping hole, into a large iron ladle, fitted into a wooden handle which rests on the ground and is steadied by another workman. A second wooden beam is fixed in front to serve as a safety device and prevent the furnace being inclined to a dangerous extent. The first bath of molten metal is carefully skimmed, and then stirred with a thick branch of green wood, the gases from which appear to effect the oxidation of some of the impurities in the metal. The furnace is righted and the molten metal emptied in at the top again, whence it percolates through the incandescent charcoal to the hearth once more. The tilting operation is again performed and the molten metal taken a second time into the ladle. A handful of wood ashes is thrown on to its surface and it is poured into the mould.

The mould used consists of two pieces, both of which are made of thick clay-work, and are bound tightly together with ropes in a bamboo framework. The top part is roughly conical in shape, and its lower portion is hollowed out to correspond with the exact

shape of the bowl required. The bottom part is hemispherical and fits exactly into the top part, just leaving sufficient space for the metal to flow around and form a casting of slight thickness. Both pieces are pierced with numerous holes, which do not go right through, but are quite sufficient to allow of the escape of the hot air from the mould through the remaining layer of porous clay, during the filling operation. The upper part has four projections which serve as handles. The metal is poured in at the top through the hollow conical portion. After being allowed to set for a moment or two, the whole mould is inverted by two men grasping the bamboo framework. By this means the surplus metal in the filling-hole is got rid of. After being placed in its former position, the ropes are untied, the framework and the upper portion of the mould removed together, and the bowl (inverted now on the solid hemispherical part), is lifted off with a pair of tongs. Should any quantity of surplus metal be left sticking on the surface it is smoothed off while the metal is still hot. The mould is repaired if necessary, and before being put in the framework for another filling, it is smoked by burning a quantity of dried grass underneath it, a special hearth being used to support the two pieces during the operation. The soot so deposited serves to prevent any sticking of the molten metal and to give a bright smooth surface to the finished casting. The personnel of a foundry of this kind consists of six men, two of whom attend to the blower, regulate its speed and charge the furnace, two others perform the tilting and tapping processes and the remaining two attend to the moulds and castings. In another shed two moulders are employed, repairing damaged moulds and making new ones. These workmen with the aid of one furnace can turn out from 30 to 40 bowls per day. They are made in seven sizes, the diameter and equivalent price of each in Têng-yüeh is given in the table below:—

	Size.	Diameter (inches).	Price. (approximate).
			R ^s . A.
1	.	29	1 10
2	.	26	1 0
3	.	22	0 13
4	.	17	0 10
5	.	14	0 6½
6	.	11	0 5
7	.	10	0 4

In April 1906, a public company was floated in Têng-yüeh under the directorship of the chief magistrate at that time. This company raised a capital equal to Rs. 30,000 approximately with which it was proposed to prospect for minerals and to exploit deposits then located in the Têng-yüeh district. The first work taken up was the development of this iron industry in the T'ien-t'ang-kuan, which had previously been carried on in a desultory fashion by the local inhabitants. I was informed that small profits were being made in this section of the Company's operations, but I do not know what has happened to it since then. It probably came to an end during the political troubles which commenced soon afterwards.

Iron smelting in the Sha-ch'iao neighbourhood.

Iron is smelted from ores obtained at several places in the vicinity of Sha-ch'iao, a small village four miles north-west of Chen-nan Chou (lat. $25^{\circ} 11'$: long. $101^{\circ} 16'$), on the main trade route between Ta-li Fu and Yunnan Fu. There was a foundry in 1909 at Hsi-ka-shan, a village between T'ien-shen-t'ang and Sha-ch'ang, where the cast iron was worked up into iron bowls of 12, 14 and 16 inches diameter. These supply the towns and villages along this trade route. The processes used were much the same as those I have just described.

At Ye-cho-ho I examined a blast furnace 25 feet high. This furnace was constructed of massive brickwork lined with clay. The ores smelted consisted of soft flaky hematite with some magnetite and they were reduced with wood charcoal without preliminary calcination. The largest mines are said to be two stages from Chen-nan Chou and to be 60 years old. I did not succeed in inspecting them. The high Chinese blast furnace used in Central Yunnan for iron smelting is usually built of massive stone or brickwork, enclosed in heavy beams held together by cross pieces. The walls are thick and lined with a siliceous paste. The furnaces are often 20 or 25 feet high and 6 or 7 feet across at the widest portion, narrowing to three feet at the hearth and at the mouth. Sometimes the top part is not tapered as in the section depicted by Rocher. The blast is always produced by a cylindrical blower usually operated by a primitive turbine. The tuyer is generally cut from hard quartzite or sandstone.

Other Localities.

I passed through P'ing-tai in March 1910. This place supplies iron to a great part of the Yung-ch'ang Fu prefecture. It lies two days to the east of the city itself and is quite close to the Mekong. The ores are obtained locally and are smelted in high blast furnaces of the untapering variety mentioned above. The crude material is worked up into bars of wrought iron for general smithy purposes, and there is also a foundry for the manufacture of iron bowls.

In the Yüan-mou Hsien district, I heard of a mine at Yi-na-ch'ang, five miles from Lung-kai, a village on the main road between Ma-kai and Ma-an-shan.

Yüan-mou Hsien.
(lat. $25^{\circ} 28'$, long. $102^{\circ} 0'$)

There is an iron ore mine at Lao-pê-ya in the Têng-ch'uan Chou district, and one stage from the town of that name. There are said to be over 10 separate workings which find employment for more than 40 men. Cast iron is made on the spot and turned into pans. I believe that these are used in the brine-boiling centres around Yün-lung Chou (lat. $25^{\circ} 48'$: long. $99^{\circ} 18'$).

Têng-ch'uan Chou.
(lat. $25^{\circ} 55'$, long. $100^{\circ} 5'$)

Hui-li Chou is supplied with iron from I-lang Ho, two stages west of the city and also from a mine and smelt at Lao-ping-wan.

Hui-li Chou.

Davies mentions a small iron-stone mine at Chiao-tso, a village near Ssü-ch'eng, on the route between Hsin-ping Hsien and Yi-mên Hsien. It lies approximately 20 miles north-east of Hsi-o Hsien and doubtless belongs to the group of small producers referred to by Lantenois as existing in that region. This particular mine is said to be worked on a very small scale and did not appear to be very productive. Most of the ore was smelted near the mine and there appeared to be enough to keep one small furnace in operation. (D., p. 206).

Hsi-o Hsien.

It was reported to me at Shui-chai in 1908, a village between Yung-ch'ang Fu and Yung-p'ing Hsien, on the main route to Ta-li Fu that iron was smelted at Tong-shan, three stages to the south. This probably refers to the P'ing-tai neighbourhood which I visited in 1910.

Yung-p'ing Hsien.
(lat. $25^{\circ} 27'$: long. $99^{\circ} 32'$.)

Near T'ieh-ch'ang, a village four or five miles to the south-west of Yung-p'ing Hsien, I found heaps of iron slags but I could not

obtain any information as to when the smelters were in operation.

Iron ores are mined and cast iron pans made at Lu-tzu, a village two stages north-east of Lu-fêng Hsien. These pans are used in the salt fields around

Lan-ching.

Hematite ores occur in bands in the local Kao-liang slates between Mo-so-ing and Yi-mên Hsien. Yi-mên Hsien. there is said to be a mine employing 30 men north of Yang-hsing-ch'uan, a village on this route.

A small mine was reported to be working in 1908 at Si-ha, near Kêng-ma (lat. 23° 32' : long. 99° 23'.) Ta-chai, on the Kun-lon Ferry—Yün Chou route, in the Chinese Shan State of Kêng-ma.

If Chinese evidence can be relied upon, one of the more important iron-producing regions of Yunnan is located around Hsi-shan-kai. This place is said to lie one stage north-west of Ta-tsang-kai, a large village near the head of the Mêng-hua T'ing valley, and about halfway between that city and Ta-li Fu. If the distance given me is correct, the deposits probably occur in the Upper Permian Red Beds series. I was informed that the mines work all the year round, that they find employment for a force of between 300 and 400 men and that they supply the cities of Mêng-hua T'ing, Ta-li Fu and Li-chiang Fu with the metal. This may be the same as the Shuang-lung-tung locality mentioned by Davies. (D., p. 148).

Yung-pei T'ing (lat. 26° 45' : long. 100° 45'). Iron ores are said to be smelted at Pê-chao-pa, six stages in an unknown direction from Yung-pei T'ing.

Ching-tung T'ing (lat. 24° 26' : long. 100° 53'). Specimens of specular iron ore were brought to me by a Chinese official in Ching-tung T'ing which were said to come from the hills near that city.

In the Yunnan course of the Yangtze, on the route from Yung-pei T'ing to Hui-li Chou in Ssü-ch'uan, Yangtze valley. between Hsin-chuang and San-tui-tz'ü, at nine miles from the former village, there are exposures of diorite traversed by films of serpentine and thin layers of practically pure iron oxides. I do not regard the occurrence as economically important.

Future of the Iron Industry in Yunnan.

The later French writers do not consider that there is any scope for the treatment of iron ores in Yunnan by modern methods. Leclère does not think that the deposits can ever contribute much to the mineral wealth of the province and believes that future demands will be met by the opening up of the vast deposits in the older rocks of Tongking. He mentions that the price of metallic iron reduced by wood charcoal was about 250 francs per metric ton and that it was employed in the arsenal at Yunnan Fu for the manufacture of guns and cannon. During the time he spent in the province, he noticed how the least fragments of the metal were collected and sold. He recalls the sale of nails extracted from European packing cases, and the surreptitious substitution of the telegraph wires by cotton threads. But these instances seem to me to be due rather to the intense frugality of the Yunnanese peasantry, and to their quick appreciation of a new and better article than their own, rather than indications of any general shortage of iron. (Le., p. 470).

The prices quoted by Lantenois are much the same, when allowance is made for the heavy transport charges from the mines to the cities. This writer is very emphatic in advising against the attempted creation of a modern iron industry in Yunnan, as he believes that it is bound to result in complete failure from the very commencement. His reasons are based on the complexity and the immense difficulties peculiar to China which may be summed up in his own words, "*la mauvaise volonté incoercible des mandarins et de la population.*"

Again, he argues that the cost of local production cannot in any case be less than that of the great European works, and that the cost of transport from Yunnan Fu to Haiphong for example, would be much the same as the ocean freight from Europe to Indo-China or Japan. The consumption of iron in Yunnan and also in Tongking is small, and, as a consequence, iron manufactured in Yunnan can never, or perhaps it would be better to say, cannot before a very long time, compete with European material either in Tongking or more distant markets like Hong-kong, Singapore, etc. Lantenois concludes that an enterprise of this kind has no possible chance of success, either in the near or distant future. (La., pp. 420-421).

Deprat in 1912 agreed with the views of his colleague. (D., p. 246).

In 1908, in a manuscript report to the Government of India, while reserving the right to express a final opinion when I was better acquainted with the iron ore deposits of Yunnan, than I was at that time, I was inclined to believe that the French writers were, quite naturally, more desirous of seeing the deposits of Tongking opened up than of advocating the introduction of capital across their frontier. A more extended knowledge of Yunnan and its minerals has led me to the later conclusion that in discouraging the expansion of iron and steel metallurgy in Yunnan on European lines, these writers were reasoning on sound economic lines. There are no iron ore deposits that I am aware of in Yunnan at all comparable in extent with those of the old crystalline rocks of India and Indo-China and as the local demand is a small one, and not likely to increase very greatly, such an industry would have to depend for its success on trans-frontier trade. The landlocked position of the province makes freight charges so high that even with railway transport available say to Tongking, to the Yangtze valley and to Burma, the local products would find it next to impossible to compete with French, Chinese or Indian manufactures in these countries or with European and American iron landed on their coasts.

That a modern blast furnace plant can be worked successfully in China is of course proved by the Han-kow works, but a situation such as they enjoy does not exist in Yunnan.

At the same time there is very considerable room for improvement in the local industry, but I am persuaded that this is a matter which may be left with advantage to the small Chinese capitalist. Future progress in the way of more systematic mining, more profitable utilisation of the ores and the closer association of the smelters with the coalfields of the province, if they come about at all, will probably come through him.

COPPER.

Copper is said to have been smelted in Yunnan for at least a thousand years and the province is supposed to have supplied the greater part of the metal used in the coinage of copper cash throughout the country. For this reason a Government department has controlled all operations in the mining, smelting and trading of copper for hundreds of years. Under the Manchu dynasty all the mines were regulated by the authorities who granted licenses

for working, fixed the price of the metal annually and strictly supervised the industry generally.

In the report of De Lagree's mission there is a detailed translation of an important Chinese work known as *Tien Nan Kouang Tchang Tou Lio*. It is really an encyclopedic account of Chinese mining and metallurgical methods, but is chiefly interesting in that it gives a complete list of all the mines working at the time it was written, and full particulars of the official regulations which at a later date exercised no small part in killing the mining industry of the province. The work was written about 1850 by Ou Ki-tche, Viceroy of Yunnan and Hu Kin-sen prefect of Tung-ch'uan Fu, perhaps the most important copper-producing district in Yunnan. In the list there are thirty-five important copper mines enumerated as well as many smaller ones. They are classified geographically amongst thirteen prefectures of the province and figures are given showing the quantities of copper each mine was compelled to supply free to the Government. From it we learn that 10 per cent. of the metallic copper produced was demanded for this imperial tribute. The local officials were held responsible for its collection and had to make good any shortage from the amounts assessed by the Imperial Bureau of Mines. Another 4 per cent. was taken for provincial purposes, and a third tax of 10 per cent. was levied to meet transport costs and repairs to roads. No less than 24 per cent. of the total copper production was thus requisitioned by the Government.

This monumental Chinese treatise became obsolete many years ago, owing to the exhaustion of some deposits and the general abandonment of mining during the great rebellion. On its authority, about the year 1850 the contributions of metallic copper for imperial and provincial purposes amounted to 6,000 tons. Too great a reliance should not be placed on Chinese statistics of this sort, but it can be asserted safely that copper mining was a most important industry in Yunnan about the middle of the 18th century.

The Mahomedan rebellion commenced about 1854 and was not quelled until 1873. In the general devastation of the country during these years the mining industry suffered a check from which it has not yet recovered.

The French metallurgist, Rocher, who at a later period became an official in the Imperial Chinese Customs Service, arrived in Yunnan in February 1871 and left it again in November 1873.

From his writings it is gathered that after the commencement of the civil war, the production of metals fell to practically nothing and that after order was re-established, the Government, though desirous of re-opening the mines as a source of revenue, hesitated to do so through fear of fresh disorders. The miners of Yunnan have always had the reputation of a turbulent class and there appears to be justification for the opinion in the fact that the preliminary riots which ushered in the rebellion commenced in the tin-producing region of Ko-chiu. Such events were not unforeseen by the astute authors of the "Tien Nan Kuan Ch'ang" as the following extract from their work shows:—

"All riches to which access is freely permitted must give rise to differences of opinion in a force of several thousands of men. Therefore it is necessary to establish such regulations as are indispensable to good order, and to see that they are observed under pain of certain punishment. When the workers of two mines quarrel over the same block of ore, no man should be allowed to carry a sword or spear, or to fashion an instrument capable of causing hurt. The formation of defensive leagues, which are often started under the pretext of fraternity must be prevented. A writer named Gien expresses the following views on such associations. 'It is rare to find a mine which does not possess a conspiracy of this nature. Mines are often the refuge places of malefactors who under the pretext of friendship are already bound together and are obliged to hide because of their crimes.' These things must be watched from the beginning with the greatest care if calamity is to be avoided." (G., Vol. II, p. 190).

Rocher states that copper is distributed throughout the province and that the mines are the deepest of any he examined. He gives an account of Chinese methods of mining, smelting and refining the metal and reproduces the list of mines from the "Tien Nan Kuan Ch'ang." (R., Vol. II, pp. 218-230). Apparently a little copper continued to be produced at the mines around Tung-ch'uan Fu during the rebellion, though all the others were closed.

Duclos, who visited Yunnan in 1896 and 1897, divides all the mines of the province into two groups as follows:—

- (a) Ancient mines and those which were active at the commencement of the rebellion in 1853 but which were abandoned then.
- (b) Mines in operation in 1896.

Under the emperors K'ang Hsi, Yung Cheng, Ch'ien Lung and Chia Ch'ing (1637-1823), the province contained fifty-four mines, most of which produced copper and could furnish in full production over 5,000 metric tons of the metal. The production of copper in 1896 is stated to have been 1,850,000 catties or 1,110 metric tons obtained from the following mines:—

Tung-ch'uan Fu prefecture (lat. 26° 24' : long. 103° 10')—			
Lao-tchang, distance from Kiao-kiat'ing,	.	.	2 days.
Ta-me-ti " " "	.	.	2½ "
Pé-hi-lou " " "	.	.	2½ "
Tong-t'an-tchang, distance from Kiao-kiat'ing,	.	.	2 "
Kieou-loung-tsin " " "	.	.	3½ "
Ty-tchang " " "	.	.	3 "
Sin-chouang-long-tchang, distance from Kiao-kiat'ing,	.	.	3 "
Má-y-chàn, distance from Kiao-kiat'ing,	.	.	4 "
Kin-hô-pien " " "	.	.	4 "
Tsin-pao-chan, distance from Tung-ch'uan	.	.	2 "
Kouan-in-chan " " "	.	.	1 day.
Tcha-ho-tchang " " "	.	.	5 days.
Ta-kong-tchang " " "	.	.	5½ "

Ch'ü-ching Fu prefecture (lat. 25° 30' : long. 103° 44')—

Tou-li-chou	}	Ch'ü-ching	2 days.
Liang-chong-kin			
Lou-fa-tchang			
Lan-tchang			

These mines only produce a little copper.

North-East and Central Yunnan.—Yung-pei ch'ang, two days from Yung-pei T'ing. Ma long-tchang and San-kia-tchang in the prefecture of Ch'u-hsiun Fu. These mines include a great number of smaller ones and produce 350,000 catties of copper per annum.

Other mines which come under the Yunnan bureau are in the north of the province or in the adjoining province of Ssü-ch'uan.

Other Copper mines.

Hui-li Chou district (Ssü-ch'uan)—

Kiang-kiuin-tchang, distance from Hui-li	. . . . .	2 days.
Lou-tchang	" " "	8 miles.
Tchou-si-tien	" " "	1½ days.

In addition to these there are two other mines, Lou-tchouan-tchang, 3 days from Lou-tchouan, and Ta-yao-tchang, 1 day from Ta-yao hien. The five mines together produced 300,000 catties of copper per annum.

In 1896 the annual imperial tribute had fallen to about 820 short tons per annum. Duclos also gives an account of the copper mines and smelters at San-kia-ch'ang in the Yi-mên Hsien district which I visited at a later date and will describe on a subsequent page. (Du., pp. 285-291).

Leclère, writing in 1891 stated that copper-mining in Yunnan and southern Ssü-ch'uan commenced more than a thousand years ago. The Imperial Department controlling the industry was founded in the middle of the 17th century. He pointed out that the statistics of this department which are still available are of little value as they draw no distinction between active and abandoned mines. Yunnan copper was then the only metal used for coinage throughout the Empire. The annual production at the end of the 17th century was 6,000 metric tons, and at the time of his travels in the country was still 1,000 to 1,500 metric tons.

Regarding the ore deposits he wrote that the ores bornite, covellite and more rarely copper pyrites are found in Carboniferous slates but such occurrences are practically abandoned. Layers of cuprite and native copper intercalated in porphyrite are very much esteemed, but the absence of explosives often makes them unworkable. Sandstones impregnated with copper carbonates are said to be found in the Trias.

The principal deposits are in Triassic limestone the mass of which is impregnated by diffusion from lodes and transformed into a carbonate containing only traces of pyrite. Such deposits take the form of zones of concretions following the natural fissures of the limestone.

The principal centres of extraction are Tung-ch'uan Fu and Wei-hsi T'ing (lat. $27^{\circ} 10'$: long. $99^{\circ} 10'$). The smelters will only accept minerals capable of producing a matte containing 20 per cent. or 30 per cent. of metallic copper. The ores are hand-picked at the mines to bring this about. Minerals which do not contain more than 15 per cent. metallic copper are thrown away and form considerable dumps. Large quantities of slags containing 3 per cent. copper must exist in the old smelting centres.

These facts are held to prove that Yunnan possesses considerable reserves of copper-bearing minerals, chiefly in inaccessible districts. Only general conclusions can be drawn and a special study of each individual deposit is necessary before its value can be determined. (Le. pp. 441-443).

A great number of copper deposits are capable of a very much larger production, even without great modification of the Chinese mining methods which are quite appropriate for scattered deposits in the Triassic limestone. Leclère thought that a production of 10,000 tons per annum was quite possible but that preliminary costs would be high. A special study of the coalfields for suitable fuel to replace wood charcoal is necessary first of all.

Copper deposits of Eastern Yunnan described by Leclère, Lantenois and Deprat.

I have not visited any of the mines described in this section as they are all situated to the north or south of Yunnan Fu, beyond the limits of my own traverses.

Deprat believes that the value of the copper deposits of Yunnan has been greatly exaggerated though he admits that there are important mines at considerable distances from the railway (D., p. 247). Most of the numerous deposits between Mêng-tzū and Yunnan Fu are not worth the trouble of examination in his opinion.

In 1903 Lantenois concluded that the copper deposits of this region are all more or less in direct association with eruptive rocks

such as andesites and basalts. He distinguishes four types of deposits :—

- (a) In contraction fissures and cracks of the eruptive rocks.
- (b) Pocket deposits at the contact of eruptive rocks and limestone.
- (c) In irregular fissures in limestone in the vicinity of eruptive rocks.
- (d) In more or less open fractures continuous across limestone and shale.

Secondary enrichment is strong and prevalent. (La., p. 406.)

This mine has been described by Leclère, Lantenois and Deprat. It is situated 10 kilometres south of Mientien, a small town some twenty miles east of Lin-an Fu. In 1905 it found employment for 70 miners and produced 60 metric tons of copper per annum. According to Deprat it is far from flourishing and will probably be abandoned. The lode seen by Leclère is worked out but another thin one carrying quartz rich in bornite and copper and iron pyrites, following an irregular fissure in an eruptive rock, is exploited. A third thin lode is also worked. The mineral extracted contains about 20-25 per cent. of copper. (La., p. 409 and D., p. 247).

This mine is situated near Pe-tchen which is a few miles north-east of Hsin-hsing Chou. It has been described by Lantenois. (La., p. 409-410). Ten years previous to his visit, it found employment for 1,000 men and produced 300 metric tons of copper per annum. Mining was then impeded by the depth of the workings. Only forty men were employed at the time of Lantenois' visit and thirty metric tons of copper were said to be produced annually, though Lantenois thinks this figure a little too high. There are three beds of mineral interstratified with sandstone floors and shale roofs. Their thicknesses are 3, 5, and 6 metres respectively. Only one of these was being worked. The mineral is found in the form of balls rich in copper carbonate. It is handpicked and washed and yields 20 per cent. of copper on smelting. The copper is bought by the Government at about 1,000 francs per metric ton. This mine deserves attention. (La., pp. 409-411 and D., p. 247).

Lan-ni-pè near A-mi Chou. (Lat. 23° 41' : Long. 103° 17'.) An old abandoned prospect with a slag heap close to it. (La., p. 411 and D., p. 247).

At the contact of the basalts and the Uralian limestones of this region there are often little fractures containing copper carbonate. They have been worked on a small scale near Mo-pe-tchong and near Lao-tchai and Sin-tchai to the north of Ho-tien. They are of no economic importance. Near Che-mo to the east of Po-hsi there are a few abandoned pits of the same description. On the eastern shore of Lake Ch'êng-chiang, in the vicinity of Min-hin, there are a number of prospecting pits in the lavas and sandstones of Moscovian age. In all these localities copper carbonates are disseminated through certain bands of rock in small quantities but, as stated before, the deposits possess no economic importance. (D., p. 248).

The mines in the neighbourhood of Lu-nan Chou have been abandoned for fifty or sixty years. They are located around Lou-méiè, Mao-chouéi-tong and Lan-nin-tsin. There are indications of sixteen old workings, which are either in the eruptive rock or at its contact with the limestone. Lantenois estimates the slag heaps to contain 10,000 or 20,000 metric tons corresponding to a production of 2,000 to 4,000 metric tons. Deprat points out that the presence of large quantities of slag is no ground to base the supposed importance of a former mine on. He writes,—“I have seen Chinese treating minerals of an inconceivable poorness; nothing discourages them; time is no object and labour is so cheap. These mines, like all similar ones in Yunnan, can be considered as non-existent for purposes of European exploitation. A Chinese will work poor minerals because no great expenditure of capital is involved, and will continue from day to day, without making large profits, often simply supplying his daily wants and seeing the return of his expenditure. In this way he will exploit the poorest deposit and then search for another to be exhausted in the same way afterwards.”

On the plateau of Devonian limestone between Lan-nin-tsin and Ta-me-ti, there are similar prospects, holes in the limestone, sometimes with a small heap of slag beside them. Lantenois has shown that these deposits consist of small nests of ore in the lime-

stone or the eruptive rock. They are very numerous, but distributed in such an irregular way, that large scale operations are out of the question. (La., pp. 411-413 and D., p. 248).

Lao-tchou-chan is a village in the valley of the Ta-chaing Ho, east of the city of Ch'êng-chiang Fu. There are two mines, one to the north and the other to the south of the village. They are both in Cambrian slates and limestones. At the southern mine of Pe-mao-tchang there is a small system of workings in the slates on a number of scattered calcite veins containing copper pyrites. The deposit is not interesting. The northern mine, called Ouan-pao-tong, displays a small vertical fracture in limestone containing a vein three or four cms. thick and containing copper minerals. It thinned out in a distance of three or four metres to a pure calcite stringer. The region is very broken up and the strata contorted and cracked. It is considered that there is little chance of finding important fractures, but rather small cracks without any continuity which are sometimes mineralised. Lantenois concludes that all the copper mines he visited in Eastern Yunnan belong to the disseminated type. (La., p. 414).

Copper Mines of North-Eastern Yunnan, described by Laclère and Deprat.

Leclère visited the important copper-producing district of Tung-ch'uan Fu in 1898; Deprat in 1910. The following notes are from their works.

This mine is in Carboniferous porphyries. One of the flows contains a horizontal band of barytes carrying native copper and its oxides. Workings started on the flank of the hill at points where the barytes layer is thick enough to permit the driving of a low adit without breaking into the igneous rock. The deposit is certainly a rich one and work was only commenced in 1897. It is difficult to come to any conclusion about its actual value because the thin portions of the deposit are not worked, though they contain as much mineral as the others. Masses of native copper too large to be brought out of the workings are left behind. About 100 men are employed. The picked ore contains 20-40 per cent. of copper. It is taken to Tung-ch'uan Fu where it is bought by the officials at about 170 francs per metric ton, including 20 francs

paid by the mine-owners for transportation. The waste material contains 15 per cent. of copper. Production could hardly be more than half a metric ton per day. Similar deposits are found in other parts of the same district. They are worked at Lou-fong-keou (15 kilometres south-west of Lou-pou), and at Kou-niou-tchang.

Lumps of native copper and copper oxides, left after the decomposition of the porphyrites are often found on the surface of the soil around Tung-ch'uan Fu. These are worked up into utensils by the inhabitants. The price of native copper in Tung-ch'uan Fu was about 510 francs per metric ton. (Le., p. 372).

The principal copper deposits worked in the neighbourhood of Tung-ch'uan Fu are comprised within the Tang-tan group, near the village of Ta-me-ti. There are four principal mines:—

Tang-tan (Tung
ch'uan Fu prefecture.)

- (1) Sin-tchang, a little above and to the west of Ta-ho. 300 miners were formerly employed here, but the mine was abandoned in 1898 owing to its distance from the smelters.
- (2) Pe-si-la, a lode in the Lower Carboniferous, 18 kilometres west of Ta-me-ti. At one time it gave employment to 300 men but was abandoned in 1898 for the same reason as in the preceding case. It was managed by Japanese working on European lines.
- (3) Lao-sin-tchang, 4 kilometres west of Ta-me-ti. Employed 200 men.
- (4) Lao-tchang with Lao-min-tsao and Sin-min-tsao. These are close to Ta-me-ti and employed 1,100 men.

At Lao-tchang there is a kind of stockwork. The ore was originally copper pyrites but it is almost entirely altered to carbonate and associated with concretions of banded barytes. At an altitude of 350 metres, the limestone massif is pierced by more than 300 workings. Drives up to 1,500 metres in length have been made on the best veins. Ores containing 20 per cent. copper are accepted by the smelters. Poorer material does not pay for treatment owing to high costs. Fuel alone cost 7 taels per 100 pounds of crude copper produced. The Imperial Monopoly bought this copper at a price corresponding to 550 francs per metric ton. Charcoal made from resinous wood is used as fuel but has to be brought from forests four stages away.

The ore from Lao-sin-tchang was a most entirely copper pyrites. The Pe-si-la ore was mainly bornite with some covellite found in veinlets in a compact state. It is a difficult ore to smelt by local methods and requires a preliminary roasting. The Japanese attempted to do this, but the scarcity of fuel made operations impossible and the deposit is now considered unworkable. The slags obtained by modern methods only contain traces of copper. The ancient slags contain about 3 per cent. of copper, but those found about the present smelters have been re-treated.

The Japanese smelters contain eight furnaces. There are others scattered about the district under the charge of subordinate Chinese officials. The furnaces consist of brasque crucibles 1.3 metres in diameter which a conical top 2 metres high. The blast enters from a tuyer immediately opposite a door, which is filled up during the fusion and only pierced by a tapping hole. The blast is produced by a large cylindrical wooden blower, the piston of which is worked by three gangs of four men each. The gangs relieve one another frequently during a working day of twelve hours, after which they are replaced by twelve fresh men. After a preliminary filling of wood charcoal brought to a red heat, small quantities of the carbonate and charcoal are constantly added and from time to time, a little sulphide ore. The slags escape through a hole pierced in the door, as the hearth fills with crude copper. When this appears at the slag hole, the furnace is allowed to cool, after which it is opened by taking down the brickwork opposite the tuyer. A fusion generally lasts five days and produces about 300 kilograms of crude copper.

The total production of Tang-tan is about 500 metric tons per annum. The crude copper is sent to Tung-ch'uan Fu and refined there by fusion in a low blast furnace and poling with rods of green wood. Part of the finished product is sent to Peking and the remainder goes to Kong-chan where there is a mint for the coinage of cash.

The Chinese officer in charge of the copper business in the Tung-ch'uan Fu prefecture informed Leclère that the Japanese spent a sum equal to four millions of francs in twelve years on the construction of the smelter, the establishment of a great number of roads and the exploitation of the Pe-si-la deposit. The enterprise had not become profitable when the Chinese-Japanese war

ended it. Copper manufacture was then taken up by the Chinese Government again. (Le., 373-377).

Twelve years later, that is to say in 1910, Deprat visited the Lao-tchang mines, which are situated two stages south-south-west of Tung-ch'uan Fu. He found that of the four groups Sin-tchang, Pe-si-la, Lao-sin-tchang and Lao-tchang, only the two latter were being exploited, the others having been abandoned. The Lao-tchang deposit is formed in the fissures of cracked and brecciated limestone. The original pyritic mineral has been transformed into carbonate as Leclère indicated, with abundant concretions of banded barytes. Very numerous underground workings follow the lines of fracture; some of them are 1,500 metres in length; the limestone massif is riddled with innumerable holes and falls are very frequent. At the time of Leclère's visit this mine found work for 1,100 men. In 1910, the labour force was much the same. In 1898 Leclère gave the production as 500 metric tons of crude copper per annum. According to explanations given to Deprat in 1910, by the officer in charge of the mine, 960 Chinese tons of crude copper were produced for the Government. This material is worth 18 taels per 100 kilograms. The Chinese ton is equal to 600 kilograms, so that the output was 576 metric tons or slightly better than it was 12 years earlier. The crude copper was still being refined at Tung-ch'uan Fu, before shipment to Peking.

The first smelting is made with wood charcoal which is brought from wooded regions three or four stages away by horse transport. This greatly increases smelting charges. In 1910, the Government paid 18 taels per 60 kilograms for crude copper. In Leclère's time the price was only 12 taels for the same quantity.

Near this pagoda, a journey of three hours from Lao-tchang, Konen-in-sa pect. pros. carbonate of copper is found in sandstones and quartzites.

Four hours journey to the north-west of Lao-tchang there

Sin-tien-fong is a working on a thin vein in altered diabase. It has only yielded traces of copper carbonates.

Lo-suy mine is one stage west of Lao-tchang at an altitude of 2,520 metres. Copper carbonates occur with

Lo-suy. phillipsite in a thin lode cutting Cambrian schists. There is a furnace in which crude copper is produced. This is refined at Tung-ch'uan Fu. The mine employs about 300 men and produces about 60 metric tons of copper per annum.

This mine is in a ravine 200 metres above the Yangtze river, 3½ stages from Tung-ch'uan Fu. It is very Mo-lou-tchang. inaccessible and the roads to it are difficult and dangerous for beasts of burden. It possesses a furnace in which carbonates of copper and copper pyrites are treated. These ores are found disseminated here and there in thin quartz veins traversing sandstones and shales. The region is said to be too crushed to contain extended fissures and the minerals form scattered deposits without continuity. Production about 15 metric tons per annum.

Deprat's résumé of the copper resources of Eastern Yunnan.

The only interesting copper mines in Eastern Yunnan are situated beyond the sphere of action of the French railway. From the Lao-tchang mines of the Tung-ch'uan Fu prefecture to Yi-liang Hsien, the minimum number of stages by horseback is eight, over detestable roads only open for part of the year; from Tung-ch'uan Fu itself to Yi-liang Hsien is twelve or thirteen stages. The mines close to the railway are not encouraging and geological conditions are such as to confirm unfavourably the impressions furnished by the deposits themselves. There is copper in the basic eruptives of the Permian and Moscovian, especially at their contacts, but always in the form of restricted deposits, immediately exhausted, and incapable of giving an output of any importance or duration. In the Permian basalts copper is found everywhere, but except in rare cases it is in traces.

Generally speaking between Yunnan Fu and Mêng-tzū, conditions offer little encouragement, the crushing and folding of the strata in the orogenic Himalayan movements almost completely dispel the hope of finding large mineralised fractures in them. (D., p. 250).

Personal Observations.

Copper Mines of the Yung-pei T'ing district.

Yung-pei T'ing (lat., 26° 45'; long. 100° 45') lies seven days' journey to the north-north-east of Ta-li Fu. After leaving the latter city, the main northerly route leading to Li-chiang Fu, is followed as far as Shang-kuan (stage I) at 16 miles. Up to this point the road is paved, in good condition, and lies between the

western shores of Lake Êrh Hai and the slopes of the steep mountains which bound it on the west. The alluvial ground around the lake is one of the most fertile spots in the province and the numerous clusters of prosperous villages bear witness to the large population which the land supports. At Shang-kuan the main northerly route is left and the Yung-pei T'ing route continues around the head of the lake for about six miles, as far as the village of Hai-ch'a-ho, whence it strikes north-east, and after crossing the low ridge separating the drainage of Lake Êrh Hai, (which lies in the watershed of the Mekong), from the Yangtze basin, the second stage of Ta-wang-miao is reached at 29 miles. A short descent from this village leads the road into the valley of a small tributary of the Yangtze flowing north-east to meet its parent stream. For one and a half more days this valley is followed passing through the village of Sin-chen, forming the third stage at 15 miles from Ta-wang-miao, and 44 miles from Ta-li Fu. After meeting the Yangtze itself near T'ien-tzū-miao, the road continues along the south bank of the river until it reaches the ferry at Chin-chiang-kai, stage four, 63 miles from Ta-li Fu. There is a gradual descent of over 2,300 feet between Ta-wang-miao and the river. Here the Yangtze is a large river, over 600 feet broad, with a swift current strangled between bare mountain ranges whose rocky slopes form the outstanding features of the landscape of this most desolate region. There is an almost entire absence of trees here and the inhabitants are a miserable mixed breed of Chinese, Lisu and Pai-i, living in small, isolated village communities. Brigands do not hesitate to attack the solitary traveller, and as in other parts of Yunnan off the main routes, wayfarers took advantage of the protection afforded by a large caravan and journeyed with me from place to place. Chin-chiang-kai is a small, partly walled village of 40 or 50 houses. It owes its importance to its situation at the ferry by which the roads from Ta-li Fu and Pin-ch'uan Chou cross the Yangtze. Another cross road leads to Ho-ch'ing Chou and Li-chiang Fu.

Yung-pei T'ing lies 43 miles to the north of Chin-chiang-kai, a distance which can be traversed easily in three days. The road is in good condition and quite passable for laden animals. It starts along the north bank of the Yangtze from Chin-chiang-kai, and then turns north up a tributary valley; after gradually ascending it arrives at the village of Man-kuan at 13½ miles. The next

stage is at Pan-hai-tzu, a small hamlet on the shores of the lake Ker-wu Hai, 14 miles from Man-kuan. Yung-pei T'ing is reached at the next stage, 15½ miles from Pan-hai-tzu and 106 miles from Ta-li Fu. After leaving the village the road continues along the east bank of the lake for a few miles before making a steep ascent over a ridge, the summit of which is crossed at the guard house of Ho-ting-tang, 8,150 feet above sea-level. After this there is a steep descent to the alluvial ground of the Yung-pei T'ing plain, and the road is almost level up to the city, a distance of 3 miles. The city is small, but possesses the usual walls. It is situated in a plain about 10 miles long and 4 miles wide at the broadest part. It has an elevation of 7,300 feet above the sea. It is under the civil jurisdiction of a second class officer subordinate to the "Fu-kuan" of Ta-li Fu. It is the headquarters of a regiment, and is the residence of the delegate from the Bureau of Mines in charge of the copper monopoly. Permission to visit the copper mines was courteously granted to me.

Between Ta-li Fu and the Yangtze, the country is almost entirely built up of igneous strata of Permo-Carboniferous age, surmounted here and there by small outliers of Permo-Carboniferous limestone. The igneous strata appear to be mainly volcanic rocks, many of which belong to the andesite group.

From a limestone outcrop overlying the lavas and found *in situ* just beyond Chin-chiang-kai, I collected numerous fossils, consisting of corals, and brachiopoda, but, unfortunately, they have not been determined yet.

Alluvial benches of considerable thickness are developed in the Yangtze valley. They are made up of sand, pebble and conglomerate banks, and are auriferous. The benches are well stratified above the level of the river, and dip down stream at low angles. The valley north of Chin-chiang-kai contains a good deal of alluvium, but it appeared to me that the limestones were unconformably overlain by red shales and sandstones of the Red Beds series. There is a well-marked conglomerate band seen in more than one place, which may mark the junction.

The ridge separating the valley of the Ker-wu lake and the Yung-pei T'ing plain, is made up of the Red Beds which here consist of rapid alternations of "pepper and salt" sandstones, red shales, fine-grained red sandstones, greyish sandstones, greenish and reddish

shales and soft bright-red shales. The Yung-pei T'ing valley seems to have been a former lake basin some 30 or 40 square miles in extent; it is bounded by the rocks of the Red Beds series or by the limestones.

The Pao-p'ing-ch'ang mines lie to the west of the city towards the Yangtze. After crossing the alluvial deposits of the plain, the road ascends the ridge separating the Yung-pei T'ing valley from that of the San-ch'uan-pa. Here fossiliferous limestones were discovered similar to those found near Chin-chiang-kai. After descending and traversing the San-ch'uan-pa plain, a sharp turn is taken to the west through the large market village of Chung-ch'u-kai, and the first stage is reached at Sin-cheng, 8 miles from Yung-pei T'ing. Near this place there are a few old levels still worked for copper ores in a desultory fashion. Leaving Sin-cheng the road continues west up the valley of a small stream, where outcrops of decomposed volcanic rocks are seen. Crossing the stream the road ascends very steeply to 7,300 feet near the small village of Ta-wa-ssü. From here it continues, still ascending to the west, but winding round the heads of some of the smaller tributary ravines, until the small stream which forms the Pao-p'ing-ch'ang valley is reached, 8 miles from Sin-cheng. Just at this point, a magnificent view of the great snowy range to the west of Li-chiang Fu is obtained.

The Yangtze, which lies six or seven miles further west, here flows in a north and south course, between two well-marked though short ranges running parallel to the river. Between these ranges there is a series of lower cross spurs separating the drainages of the smaller tributaries. Pao-p'ing-ch'ang is situated almost on the crest of one of these, dividing the watersheds of the Wu-lang Ho and the next stream, which joins the Yangtze 20 or 30 miles further south.

The country is built up of contemporaneous igneous strata of Permo-Carboniferous age, the decomposed outcrops of the flows being seen in the gullies where the watercourses have removed the overburden, but, as a rule, a red clayey soil covers the ground and forms the smooth outlines of the rounded mountain tops. There is a little pine forest, but most of the trees have been cut down for charcoal manufacture. Some of the bare slopes are cultivated by Lisus and Mosos.

Pao-p'ing-ch'ang is a typical Chinese mining camp. The sides of the valley are covered with dumps and have been dug up repeatedly in the search for ores. The entrances to the levels are perched in all kinds of places on the steep slopes, the spoil heaps forming long glissades down to the stream far below. Great heaps of copper slags are scattered around. The village is small and badly built, the water supply is poor and supplies of every kind have to be carried in from a distance.

A prospecting adit was being driven into the hill-side from the bottom of the valley, one mile to the west of Sin-cheng workings. Sin-cheng. Its length was about 100 feet. Another level entered the hill at a lower horizon in a north-westerly direction. The only indications of ore were at the face in the latter and consisted of two thin stringers of malachite in a decomposed and broken igneous rock. On the opposite side of the valley I saw three levels one above the other. Very little ore was being obtained, though extensive work was said to have been carried on formerly. Ruins of furnaces exist in the valley, but the small amounts of ore obtained at the time of my visit were sent to Pao-p'ing-ch'ang for treatment. I do not regard the locality as at all promising.

The youngest strata around Pao-p'ing-ch'ang are the white limestones of Permian (?) age. They Pao-p'ing-ch'ang geology. surmount the tops of the hills to the north and north-west, and are so white that from a distance one is liable to mistake their scattered outcrops for snow drifts. I think that the dark-coloured, fossiliferous limestones of Permo-Carboniferous age come beneath them, and are themselves underlain by a thick series of shales and sandstones of various shades of yellow, white and red. They crop out near the village with a dip of 53° to the east-south-east, but further down the valley the dip is not so high. The portals of the tunnels go through these rocks.

In association with them is the volcanic series, made up of lavas, tuff bands of reddish and greenish shades, ash beds of darker tints, with layers of shale and grit intercalated in the flows. The tuffs weather easily into red and green spotted angular fragments; the shales form easily broken, nodular masses and there is a great variety amongst the true igneous rocks. The lavas are often very altered at the surface and it is not always easy to recognise their true characters.

There are very numerous old workings in the valley, but the deposits which were being worked at the time of my visit were entered from both sides of a spur which cuts into and narrows the valley near the point where it turns north-east; (further towards its head, the valley has a north and south direction). The mines are from 1 to 1½ miles from the camp to which they are joined by a good mule track. I inspected the workings entered from the south side; time did not permit of my visiting the others on the opposite side. The underground workings that I went through were of great extent, and I was in them for some hours. It is quite impossible to describe them in detail, without the preparation of a plan. They turned and twisted in every direction and formed a perfect labyrinth of underground galleries. Suffice it to say that the actual workings were amongst the best that I have seen in Yunnan. The timbering especially deserved much praise for it was done with a practical knowledge and care which betokened considerable experience. The main roads were high and well driven. The ventilation in the main ways was good and obtained by means of rises through to the surface and upper workings. In the remoter parts of the mine the air was very foul. There was not much water in the mine except in the lowest workings whence it was raised into the drainage adits by means of the usual bamboo pumps. The general impression I received was that the mine was about exhausted as far as it was possible for the Chinese to go down. There was no proper system of working and thin quartz stringers were being followed in all directions. These carried sulphide ore in the form of erubescite with smaller quantities of chalcopyrite. Chalcocite, malachite and azurite were also identified. In one part of the mine I came across an old stope, which seemed to indicate the original presence of a large lode, 5 or 6 feet thick. The miners confirmed this and said that it ran out 10 or 15 years before. Decomposition and metamorphism of the country rocks had been very great and it was impossible to arrive at any conclusions regarding the formation of the ores during the short time I was permitted to stay in the mine. I am inclined to think that the lodes were in very irregular fissures of great variation in size, traversing shales, sandstones and limestones. They also appear to have entered the eruptive rocks in contact with them.

The ores are carried to the surface in baskets by boys, and after

the larger pieces have been broken up, the material goes to the sorting tables, each of which finds employment for 8 or 10 women and girls, who are very skilful at their work. The rich pieces are picked out and placed in baskets. The remainder goes to the dumps. The latter consist of the gangue and also of the low-grade ores, disseminated sulphides and carbonates. The water percolating through the dumps was of a bright blue colour and appeared to bear an appreciable quantity of copper salts in solution.

The rich picked ores, consisting chiefly of erubescite and chalcopyrite are carried down to the smelters, which are situated in the village. They are

Ore treatment.
first of all roasted in large quadrangular kilns for three days with ironstone, charcoal and wood. The caked masses from this operation go into the large blast furnaces; the smalls and dust are washed, the heavier portions kept, and smelted in a special furnace of smaller dimensions. The preliminary calcination appears to drive off volatile impurities, to reduce the ores to a certain extent and to prepare a hard porous cake in good condition for the final operation in the blast furnace. Three sizes of blast furnace are made use of generally in benches of six. The largest are from 20 to 25 feet high with a covered-in chimney, but with a long opening in front, above the wall of the actual reaction chamber which is of course much smaller. The other furnaces are about 15 feet high, and there is also a still smaller type. The smelting operation takes three days to complete in the biggest furnaces, working day and night, and twelve hours in the smallest type. The blast is supplied from large cylindrical blowers worked by relays of coolies. The molten metal is not tapped, but when the reaction is completed the front of the furnace is broken in, leaving a bath of molten metal at the bottom in the hemispherical-based crucible. This is allowed to cool, and the cooling process is hastened by spraying rice water on the hot surface, which as it solidifies is removed in plates. The charges for the largest sized furnaces are said to be as follows:—

Calcined ore	40 loads, say	3 tons.
Iron ore	20 " "	1½ "
Charcoal	40 " "	3 "
Limestone	20 " "	1½ "

The amount of copper produced, according to my Chinese informant, may be anything from $\frac{1}{8}$ to $\frac{1}{2}$ ton.

The Pao-p'ing-ch'ang mines are said to be over 200 years old and to have been opened in the Ch'ien Lung dynasty. About 100 years ago, the mine is related to have produced over 1,785 tons of metallic copper per annum, and to have found employment for five or six thousand men. In the K'ang Hsi dynasty an average of 110 tons of copper was produced annually. But of late years the production has fallen off rapidly and in 1907 it only reached about 20 tons. In the year of my visit, 1909, production witnessed a marked improvement and it was estimated that 60 tons would be turned out. About 8 years before this the total output of all the copper mines of the Yung-pei T'ing district was some 150 tons per annum, but six years later this had fallen to approximately 30 tons. The later improvement was therefore a well-marked one though it was probably brought about by the installation of the provincial mint in Yunnan Fu and the endeavours of the Local Government to stimulate the supply of copper for coinage purposes.

The mining and smelting operations at Pao-p'ing-ch'ang are controlled by a syndicate of twelve partners. These men are not natives of the district but come from the metallurgical centres of Tung-ch'uan Fu and Lin-an Fu. They were supposed to sell all the metal produced to the Government representative in Yung-pei T'ing, who paid for it at prices fixed from time to time by the Central Bureau. As a matter of fact in this isolated area far away from the centre of the administration, there was admittedly a considerable amount of corruption, smuggling and contraband trade in copper.

About 250 men were employed at the time of my visit. The miners were paid at the rate of Rs. 3 *per mensem*, the carriers from Rs. 1-6-0 to Rs. 2 *per mensem*. The women who sorted the ore received 50 cash each per day. The surface coolies about the smelters received much the same wages. These remarkably low rates of pay do not appear so ridiculous when it is remembered that the Syndicate also supplies all its labour with food, salt, shoes and tobacco.

Other Copper mines in the Yung-pei T'ing district.

Copper ores are worked at the following localities in the Yung-pei T'ing district:—

Mu-~~erh~~-p'ing-ch'ang.

Ta-pao-ch'ang.
 Pa-sa-la.
 Hsi-si-ti.
 Tung-ch'ang-ho.

Some of these are merely prospects finding employment for a few miners. None of them is equal in size or importance of production to Pao-p'ing-ch'ang. They are all situated from one to three stages to the south of Pao-p'ing-ch'ang, in the unsurveyed and mountainous country between it and the Yangtze.

Copper Mines of the Li-chiang Fu prefecture.

At Yung-pei T'ing I obtained the information that the following mines produce copper ores in the prefecture of Li-chiang Fu, which borders the Yung-pei T'ing district on the west.

Hei-pei-shui.
 Ku-ho.
 Lo-tzu-chüeh.

There is no agreement between my list and that given by Rocher 30 years before. I was at first inclined to imagine that his Tê-pao-p'ing might be identical with Pao-p'ing-ch'ang, but a Chinese scholar to whom I submitted the characters, says that this is not so. Rocher mentions a mine called Pao-p'ing in the Li-chiang Fu prefecture, but this cannot be the same as Pao-p'ing-ch'ang, as it is said to be a silver mine, unless Rocher was mistaken in the product.

San-chia-ch'ang Copper Mine, Yi-mên Hsien district. (Lat. $24^{\circ} 39'$; long. $102^{\circ} 10'$; visited April 3rd, 1908.)

The small copper-producing centre of San-chia-ch'ang is situated five stages to the south-west of Yunnan Fu, Route. in the upper valley of the eastern headwaters of the Yuan-Chiang, the "Red River" of Tongking. Between Yunnan Fu and Yi-mên Hsien (stage 3), Carboniferous, Permo-Carboniferous and Red Beds are found, faulted against rocks which I regard as Cambrian on lithological grounds. Around Yi-mên Hsien, limestones are again met with, but they only stretch a few miles further west when they are faulted against a series of ancient slates. In the vicinity of San-chia-ch'ang, broken bluish-grey slates form the steep hill-sides, covered with loose screes on

the eastern bank of the river, while on the opposite bank, limestones crop out. The latter are exceedingly broken up near their faulted contact with the slates, and every variation from coarse breccias with large angular fragments, down to cracked and broken fine-grained rocks can be found. The river flows in a gorge at an elevation of approximately 4,000 feet, but within four miles on either bank, the bounding ranges attain heights of over 8,000 feet. There is a great limestone precipice rising up immediately behind the village. It is noteworthy that rolled blocks of a red granite were seen in the stream-bed.

The place was visited by Duclos in March 1897, (Du., pp. 291-294), who gathered the information that
 Mines, several copper mines were worked in this region before the Mahomedan revolt. At three stages down the river the mines of I-tou, Ho-la and Tze-mou were situated. The mine of Ouang-po seems to have been some twelve miles further up the valley above San-chia-ch'ang. In addition to these there were several prospects. All ore was sent in to San-chia-ch'ang, and the supply was sufficient to keep four furnaces in continual operation. Only one furnace was working in 1897, and this was the state of affairs in 1908 at the time of my visit, though a second furnace was kept ready for blowing in if necessary. In 1897 the annual production of metallic copper was about 40 metric tons. In 1908, as far as I could gather, it had fallen to half that amount. An officer from the Bureau of Mines was stationed in the village to buy all the metal obtainable and forward it to the capital. In 1897 only one mine was being worked to the south of the village. This appears to be the mine I saw in 1908. The main entrance was high up on the mountain side, $1\frac{1}{2}$ miles south of the village. The road to it was very bad and impassable for animals. Judging from the extent of the workings it was of very considerable age. It took me between $\frac{1}{2}$ and $\frac{3}{4}$ hour travelling underground to reach the first working place, the roads twisting and turning in every direction. The country rock appeared to be an altered limestone, and the ore chalcopyrite with small amounts of enriched sulphides. According to Duclos, several well-marked lodes exist, but I was unable to trace any definite veins and the minerals I saw occurred in badly defined and rather thin zones of impregnation. However I was only able to examine a small portion of the mine. The ventilation was fairly good and was produced by rising

through to the open air in small inclined shafts. Timbering had been introduced wherever necessary. The labour employed consisted of about 20 men and all low grade ore was being thrown away on dumps near the mine.

I doubt if there is much left in the mine in the parts worked by the Chinese, but it might be worth examining to see if the deposits extend to greater depths than they have been able to exploit them.

Ta-tsang-kuan-miao copper prospect, Mêng-hua T'ing district. (Lat. $25^{\circ} 15'$: long. $100^{\circ} 20'$).

This locality is situated in a ravine formed by a small stream flowing from the north-east to join the Mung-hua Ho, about 2 miles to the east-south-east of Ta-tsang-kai, a village about 10 miles north of Mung-hua T'ing on the Ta-li Fu route.

The road is in good condition except for the last $\frac{3}{4}$ mile, where it ascends the narrower part of the ravine. Prospecting commenced here in 1909 and when I examined the place in March 1910, work was still in an exploratory stage.

The country rocks consist of soft red and white sandstones interbedded with well-laminated grey shales striking north-east to south-west and dipping south-east at about 40° . Reddish grits and conglomerates with quartz and other pebbles up to one inch in diameter are common in the vicinity. These rocks belong to the lower horizons of the Red Beds series.

There are two inclined drives on the south bank, following a well-defined shale band with its dip. The first of these was said to be about 300 feet long, and enters the hill about 50 feet above stream level. The portal was timbered but the face was not visible as the drive was flooded. The second tunnel was 80 feet above the stream and follows the same band with its dip slope. It was commenced when the lower working was flooded out and had been driven about 120 feet. The roof and sides were standing well and no timbering was necessary. Traces of malachite were visible in the roof. From specimens of ore shown to me at the mine, I concluded that the shale contains pieces of bornite about the size of pigeons' eggs coated with thin crusts of decomposed matter containing green and blue carbonates of copper. The central cores of the nodules were clean and of good appearance. No information was obtainable as to the amount of ore extracted,

Other Occurrences in the Mêng-hua T'ing district.

An abandoned copper mine is stated to exist at Hua-pang to the north-west of Ta-tsang-kai.

Copper is said to be mined and smelted near Kung-lang, a large village on the northern side of the Mekong about half way between Mêng-hua T'ing and Yun Chou. (Lat. $24^{\circ} 30'$: long. $100^{\circ} 10'$).

Sha-ho-ch'ang copper mine near Yung ch'ang Fu. (Lat. $25^{\circ} 6'$: long. $99^{\circ} 10'$).

Sha-ho-ch'ang lies about 15 miles to the north-north-west of Yung-ch'ang Fu, as the crow flies. It is best reached by the northern route which skirts the edge of the Yung-ch'ang Fu plain, and leads across the Salween-Mekong divide into the valley of the Salween. The mine is in the narrow valley of a small tributary of this river. The divide attains a height of about 9,000 feet. After leaving the alluvium of the plain a series of ancient greenish slates, clay schists and phyllites is met with, extending to the immediate vicinity of the mine. Here hard reddish sandstones are found, striking west-north-west to east-south-east. They are intruded by a very altered basic rock.

Ancient slag heaps of considerable extent occur in the neighbourhood and the mine is said to have been in a very flourishing condition about 20 years ago. It is not apparent why operations were stopped, but in 1909 at the time of my visit re-opening was taking place under the patronage of the local Chinese authorities in Yung-ch'ang Fu. The new work had only commenced a few weeks before my arrival, but at that time over 70 men were employed and metallic copper was being made.

The workings were all in the steep hill-side to the east of the village. There were indications of numerous old workings, while four or five places were being opened up, but did not extend for any distance. In one adit I noticed a quartz vein from 5 to 9 inches in thickness containing abundant chalcopyrite. The diabasic country rock on both walls was impregnated with the same mineral. In the other workings, similar impregnated ore was seen. Near the surface oxidation had taken place with the formation of copper carbonates.

After mining the ores are handpicked, and the poorer material freed from gangue by crushing and washing. After a preliminary

roasting the material is smelted in a large blast furnace of the usual type. The metal is cast into cakes weighing about fifty pounds each, and the production had then reached between two or three tons per month.

Other Localities.

Copper sulphide ores occur in the Ming-kuang valley, north of Têng-yüeh T'ing. Oxidised copper ores occur with galena and zinc blende at the Tung-shan mines above Hsiao-hsin-kai, and chalcopyrite occurs with pyrite and galena in the complex ore from Hung-tu-hai in the Ming-kuang. In 1908 attempts were made by a Chinese syndicate to treat these ores for copper, but they were not successful.

Films of copper carbonates occur in the Carboniferous lavas between Hung-ai and Yunnan Hsien and are probably formed from the decomposition of copper pyrites. The occurrence is of no commercial importance.

A large copper mine is said to exist to the north of Ting-yüan Hsien. I tried to reach it in 1909 but was prevented by bad weather.

In the Chin-tung T'ing district I heard that a small mine was producing copper at Lao-tsang near Chu-kai. The dark Mesozoic limestones in the vicinity of Hsiao-lo-ho contain cracks filled with films of copper carbonates. I noticed that open cuts were being made on them, one mile south of Tsu-kai-tang in 1910, but the occurrence did not strike me as valuable.

The district of Hui-li Chou, now in the province of Ssü-ch'uan, but mentioned here because it once formed part of Yunnan is famous for its copper mines. According to Davies there is a mine at Lu-ch'ang, six miles south of the town. (D., p. 214). Some of the mines are mentioned in a recent article by Mr. Herbert W. L. Way. ("The Minerals of Sze-chuan, China." *Min. Mag.*, July 1916, pp. 20-23). I noticed small heaps of copper slags at several localities on the southern route between Hui-li Chou and the Yangtze. Davies has recorded that copper and iron are mined in the hills around the northern part of the Hui-li Chou valley and expressed the opinion that more mining might be done if the Lolo country to the east were more settled. (D., p. 222). It is interesting to note that all the Chinese copper-smelting in this region is done with coal or coke. (D., p. 215).

Copper ores occur in the Wei-ning Fu district of the Kuei-chou province but as this town is only 20 miles from the eastern frontier of Yunnan, it is worth while reproducing here such information as exists upon them. This is taken from Davies' account of his journey from Yunnan to Kuei-chou by the Yunnan Fu, Chu-ch'ing Fu, Hsuan-wei Chou route. On the second day out from Hsuan-wei Chou, the large village of T'ang-t'ang is passed. This is in Yunnan and is the headquarters of the lessee of the copper mines in the neighbourhood. In 1899 the mines, located in many places in the vicinity, were not producing as much as they used to. Three stages from Hsuan-wei Chou brings one to Yao-chou in Huei-chou, where Davies examined a mine in the hills two miles to the west of the village. He has given the following account of it :—

“ This mine, they say, was formerly very productive and 2,000 men are said to have found employment here. At the time of my visit there were not more than 100 miners at work. They live in little huts scattered about the valley, and there are three furnaces constantly kept burning to smelt the ore they dig out. The ore is mined out of the solid rock of which the hill is formed. There are no deep shafts ; they cut caves out of the hillside, and the miners often live in the caves they are working in. They use hammers and iron wedges, and they say a man can get out a mule load of ore in two days. The ore varies a good deal in quality, and is sold for from two to seven mace a mule load. Taking a load as 130 lbs., this comes to from sixpence to one and ninepence for 100 lbs. The best ore is of a purple colour and is said to produce 10 per cent. of copper. The lessee of the mine pays 500 or 600 taels a year to the Government for the right of smelting, and the miners are obliged to sell the ore to the lessee. The copper produced is sent to Kuei-yang Fu, the capital of Kuei-chou province, and is there used for coining into cash.” (D., p. 165).

The only importance of the Wei-ning district is said to be in its mines of copper, lead, silver, iron and zinc. In the town itself Davies lived in the Government mining office and remarks,—“ They have a lot of boilers and other mining machinery here, which are the property of the Yunnan Province Government, who have never used them and want to sell them, but are hardly likely to find a purchaser here.” (D., p. 167).

According to Davies the price paid by the Government for copper in 1899 was equivalent to £28 per ton.

The Future of Copper Mining in Yunnan.

The previous pages show that copper ores are widely distributed throughout Yunnan, and that at one time copper mining was the most important branch of the mineral industry in the province. The decline of the past fifty years is due to a number of causes; the following are the more prominent internal ones:—

- (1) partial exhaustion of rich ores above ground water level;
- (2) political disturbances and strangulation by too strict an official control;
- (3) destruction of the forests and consequent lack of large quantities of charcoal at reasonable prices;
- (4) difficulties of transportation.

Although I believe that the earlier French writers were to some extent led astray by too complaisant an attitude towards Chinese accounts and formed too exaggerated an opinion of the potentialities of the copper resources of Yunnan, I do not accept in its entirety Deprat's rather gloomy prediction. It is admitted that there are no important deposits within reasonable distance of the railway which now runs from Mêng-tzū to Yunnan Fu, but I wish to look further ahead when other lines will doubtless traverse the province and open up areas which are now most inaccessible. I do not believe that there are any important deposits unknown to the Chinese, unless they are situated in the remoter regions of Yunnanese Tibet, neither do I think that the lean deposits of small extent will ever lend themselves to exploitation on modern lines. At the same time I am convinced that Yunnan possesses considerable resources of copper ores at depths at which indigenous methods have failed to reach them. While it is impossible to point to any particular example, I conclude that the larger deposits in the districts of Tung-ch'uan Fu, Wei-ning Chou, Yung-pei T'ing and perhaps Lin-an Fu, Li-chiang Fu and Wei-hsi T'ing, merit careful individual attention and that some of them will probably repay the attention they receive.

The future expansion of copper mining and smelting will depend on the scientific application of the most recent practice and this cannot be done either by European or Chinese until better transport facilities are created in most cases, and a more generous attitude is adopted by the Administration towards all.

LEAD AND SILVER.

Although it seems probable that in the past Yunnan has furnished large quantities of silver, obtained in most cases by the cupellation of argentiferous lead, to meet the demand in other parts of China, the available information regarding the deposits themselves is but meagre. The Chinese exploitation of the Bawdwin mines in the Northern Shan States of Burma, for silver, and the interesting records of their past history which extend over a long period of time, prove how far afield the Imperial Government was once prepared to extend its operations in search of silver.

Some idea of the importance of lead and silver in Yunnan about the middle of the 18th century can be gleaned from Rocher's revision of the Tien-nan-kuan ch'ang lists. The following details are taken from that source. (R., pp. 252-259).

The Tung-ch'uan Fu prefecture possesses numerous deposits of argentiferous galena. The mine of Mien-hua-ti, to the north-west of Ch'iao-chia, on the borders of Ssü-ch'uan, was very productive.

The following mines are also mentioned :—

Ch'in-niu north-west of Ch'iao-chia ;

Ch'iao-lien, east of Hui-i ;

Kuan-shan.

The last mine was only opened a few years before the Chinese list was prepared.

The mine of Lo-ma, in the Yung-shan Hsien sub-division, was situated at Lung-t'ou-shan and was famous for the large amount of silver contained in its copper ores. It was practically ruined in the rebellion. Three other mines produced argentiferous galena. They were situated at Niu-kai-tien, Lan-shih-liang and at Hsin-kai-tzu ; the two latter produced an ore very rich in lead, but containing little silver.

In the south of this prefecture two deposits of galena were known, but the disturbed state of the country interfered with their working in the seventies.

Several deposits of galena were known in this prefecture. The mine of Kuei-i produced a very rich galena, but after the rebellion its production became very small.

The silver mines of Yung-ch'ing and Ma-lin were situated to the south of the Ning-tai copper mine, itself 520 li to the south of Shun-ning Fu. These mines were more or less under the control of the prefect of Shun-ning Fu, although in the territory of a semi-independent chief, but they fell into the hands of the rebels and after that reported no production to the Government.

Lead and gold occurred with the copper ores from the Chin-ch'ai mine, 90 li south-west of Mêng-tzū, which was opened during the reign of the emperor Ch'ien-lung.

Silver occurs with the tin, copper, zinc and iron ores of the Ko-chin massif. The mine of Lung-chou contained numerous lodes of argentiferous galena, and the rich deposits of the Mêng-ho mine were no less remarkable.

The Pai-yang mine, north-west of Tli Fu, in the Yün-lung Chou district, was at one time worked only for its silver minerals, but, later, copper lodes were discovered, and when the rebellion broke out, both metals were being produced. The Ta-kun mine, situated a little to the north of the former, was opened a short time after it but its production was not so important. There was another silver mine at Ta-mei-ti.

The silver mines of this prefecture though not numerous were very productive. Yung-shen mine was situated to the south-west of Nan-an Chou, in the Chin-t'i mountains. Shih-yang mine, perhaps the richest, was opened in the 24th year of the Emperor K'ang-hsi. Ma-lung mine was also situated to the south-west of Nan-an Chou. The ores from this mine contained gold.

Hui-lung copper mine used to produce very rich argentiferous galena. Silver minerals were also mined at Lan-shui-t'ou and Pao-p'ing.

Only one silver mine in this district paid the Imperial dues. It was called San-tao-k'ou, and was situated in the Yung-p'ing Hsien neighbourhood.

Several deposits of argentiferous galena were known in this region. The silver mine of Tai-ho was situated to the south of Hsin-p'ing Hsien and was very productive; it was closed during the

rebellion. Other deposits, some of which were exploited by the hill tribes, were located west of the same town.

According to Joubert, numerous argentiferous lead mines existed near Sin-kai-tse, six leagues from Co-kouy, on the banks of a river bearing the same name. The quantity of silver produced seemed large enough to cover the costs of exploitation and transport of the lead to the markets of Chung-king, 100 leagues away, on the Yangtze. Very rich and easily worked argentiferous lead mines were situated near Tung-ch'uan, and at Mêng-tzū, five stages to the west of Lin-an Fu. The extensive deposits found around the town of Kouï Fu, on the banks of the Yangtze, were considered as the most likely to be worked. (G., II, p. 161).

Leclère recalls that the metallurgy of lead, silver and zinc forms part of the Imperial Monopoly. He regarded the importance of the deposits as not great enough to justify expenditure on communications to them. The development of the lead, silver and zinc mines was subordinated to the production of copper. Lodes containing lead ores are not as numerous as copper lodes and they are only well developed in certain localities, notably around Kochiu and Wei-ning Chou. In the former locality, the vein at Long-teou-tchai was certainly extensive and very regular, though when Deprat wrote in 1911, the workings had been abandoned. The silver was extracted from the lead by cupellation, and the slags were often rejected. It was clear that many of the residues accumulated under such a system would be amenable to European methods. Leclère estimated the annual production of metallic lead in Yunnan as approximately 3,000 metric tons.

Lantenais received information regarding an argentiferous lead mine at Pan-san, one stage to the south of the Ouai-teou-chai mines where there were estimated to be 10,000 metric tons of lead slags probably worth re-treating. Lead is also said to occur in the Kai-hua Fu and Mêng-tzū Hsien regions. At the latter place, Lantenais examined specimens of antimonial galena and of quartz with mispickel which came from these mines. The veins appear to be related to the granites of the district. (La., pp. 421-422.)

Duclos calculated the annual production of lead at 2,598 metric tons in 1897. (Du., p. 285). He remarks on the difficulty of separating lead and zinc mines owing to the constant association of

galena and zinc blende in Yunnan. The following list compiled from Chinese sources is reproduced:—

Tung-ch'uan Fu prefecture. Kong-chan-tchang, two stages from Tung-ch'uan Fu produced 1,120 tons of zinc and 863 tons of lead.

Pe-cha-po, also two stages from the same city produced 10,000 taels of silver and 372 tons of lead.

Tsay-te-k'ou, two stages from Kiao-kiau-t'ing produced zinc.

Kouang-chan mine, 60 li to the north-west of Tung-ch'uan yielded a very argentiferous galena. After cupellation, the lead was sent to Ssu-ch'uan where it was re-treated, and still yielded a little silver which contained traces of gold. In the same massif high-grade blende was found, but as the price of the mineral was low, very little traffic was done in it.

Fou-lay-tchang, one day from Wei-ning Chou Wei-ning Chou district produced 536 tons of lead and a little silver.

Siao-in-tchang produced 24 tons of lead and a little silver.

Sin-pao-tong, three days from Wei-ning Chou produced 24 tons of lead and a little silver.

Tchou-tsin-tchang, one stage from Wei-ning Chou produced 18 tons of lead and a little silver.

Pien-kiao-tchang, one and a half day's journey from Wei-ning Chou, produced 238 tons of zinc and twice that quantity of lead.

Ta-pao-tong, two days from Wei-ning Chou produced 30 tons of lead and 416 tons of zinc.

Mey-houa-chan, one stage from Wei-ning Chou, produced 178 tons of zinc and 12 tons of lead.

Loung-kay-tze, two stages from Wei-ning Chou, produced 178 tons of lead and 60 tons of zinc.

Y-long-ho-pa, two stages from Wei-ning Chou produced 238 tons of zinc.

South and south-east of the province. Ta-lang-tchang, two stages from Ta-lang T'ing, on the route from Yuen-kiang to Ssü-mao, produced gold and silver.

Tchen-pien-tchang, two stages from Tchen-pien T'ing, produced gold and silver. Three stages from the same city was situated the Mo-la-tcheng mine which produced silver and gold, while two stages away Sin-tchang was located which produced silver and gold.

The mining and metallurgy of lead, silver and zinc, is controlled in much the same way as copper. All work is carried on with the permission of the Government, and is superintended by the mandarin-delegates of the Bureau of Mines. The rough metals are handed over to the officials for sale which is not permitted privately. Contributions of both lead and zinc have to be made annually to the Imperial Exchequer.

Davies has drawn attention to the fact that there is an export trade in lead and zinc as well as copper from Yunnan to the Yangtze valley. (D., p. 318). Regarding the occurrence of silver, he writes "This metal is if anything more abundant than copper, and one can seldom travel far in Yunnan without seeing or hearing of silver mines. I doubt if there is any large district in the province which does not produce silver. Many of these mines are well worked, and Yunnan supplies much of the silver used in other parts of China." (D., p. 314).

The same writer mentions the occurrence of lead and silver in the Ming-kuan valley and at Hsiao-hsin-kai, which I have visited and describe in a later paragraph. (D., p. 314). He also mentions the existence of silver mines in the Wei-hsi T'ing districts. In the province of Kwei-chow he notes the prevalence of lead, silver and zinc ores in the Wei-ning Chou district, (D., pp. 166-167.), and makes the following observations on mining at Kung-shan, a large village on the route from Wei-ning Chou to Tung-ch'uan Fu, just across the Kwei-chow border but in Yunnan:—

"Lead and zinc are the two chief minerals, and the lead ore also produces a small quantity of silver. I was told that the output of lead averages 400 pounds in a day. The zinc is got out of very deep shafts, extending they say several li into the hillside. I did not test the exact accuracy of the statement but I went a little way down one shaft and it certainly seemed a very deep one. They are not sunk straight down but are sloped so that a man can walk down them, though the passage is so low that he has to keep in a bent position most of the way." (D., p. 171).

Lead-mining in the Ming-kuan.

The Ming-kuan is the name given to part of the valley of the No-lo Ho, a tributary of the Lung-chiang which is the Shwe-li of Upper Burma. It lies between 30 and 40 miles due north of Têng-yüeh T'ing and about 24 miles due east from the frontier in

the vicinity of Myitkyina. The valley itself is not difficult of access though the Chinese roads are by no means good. I visited it in December 1907. At that time the prospecting rights had been secured from the Chinese Government by a Cantonese Chinese Wan Kun, who with three or four other Cantonese and a number of local Yunnanese was working in the valley.

That the Ming-kuan has been the seat of a considerable copper and lead smelting industry in the past is proved by the large number of old adits which enter the hills at various places, by the remains of ancient furnaces, and by the heaps of slag which bear witness to the large quantities of ore smelted. I discovered slag heaps at various places, the largest being located at Hsiao-hsin-kai, Hong-too-hai, Kan-tung-pa, and in the valley which forms the pass leading from the latter place to Kai-tou. There is some reason for supposing that these slags could be re-treated profitably by modern processes, and the large quantities which exist alone make the Ming-kuan worthy of attention. I was told that some of the heaps were three hundred years old, and doubtless the smelting of lead ores and the cupellation of the metal for its silver content have been carried on more or less continuously up to the present time. In 1907 there seemed to be a revival taking place as I noticed furnaces in the course of construction at four different places.

The ores from the various mines worked by Wan Kun were brought to Hsiao-hsin-kai and mixed. After several roastings and washings, they were reduced with charcoal in a small blast furnace of brickwork, about ten feet high, said to be capable of dealing with one ton of ore in twenty-four hours. The blast was produced by the Chinese cylindrical blower worked by a water-wheel. The crude lead alloy from this furnace was then cupelled for its silver, this operation being carried out in a dome-shaped furnace in which the fuel is supported on a hearth above the charge. Attempts were being made to smelt the copper ores which are also obtained locally, but the small type of furnace seemed incapable of producing more than a very crude copper matte. I examined mine workings at the following places:—

Hsing-ai-ch'ang ;
Tong-shan ;
Hong-too-hai.

Hsing-ai-ch'ang is situated in the valley of a small tributary which enters the No-lo Ho from the east about 6 miles to the north of Ku-tung-kai. The actual workings are very inaccessible and the track to them exceedingly bad. There are several ancient drives in the vicinity from which ore has been won in the past. From one of these I obtained some poor specimens of malachite. A new exploratory adit had been driven into the granite for about 240 feet. From the end of it there was an easterly cross-cut nearly at right angles, and about 150 feet in length. The mining had been carried out with judgment and skill, the levels were straight and high and the timbering good. About ten men were at work and day and night shifts were being carried on. At the end of the cross-cut there were several good stringers of oxidised lead ores, and as a prospect the place looked promising. The strike of the granite, which appeared to be intruded into crystalline limestones, was north 10° east.

The Tong-shan workings are situated on the hills above the village of Hsiao-hsin-kai, to the east of the No-lo Ho stream. As at Hsing-ai-ch'ang, there are numerous old levels now abandoned. Three workings were yielding ore at that time. They were all in limestone, which is very hard and considerably broken up. The main adit extended into the hill for over 600 feet. It was not a good piece of work, as it sloped very steeply and was low and tortuous. No timbering was necessary and the place was dry. It seemed to me that the ore occurred as in-fillings in certain parts of the broken and cemented limestone, but owing to the Chinese practice of heating the working face to lighten the labour of winning, I was not able to make a very careful examination. Galena, zinc blende, limonite and oxidised copper ores occur. I was given some very good samples of galena from this mine. About eight men were employed but the work could easily be extended.

Hong-too-hai is the name given to a mountain situated on the east side of the valley about 3½ miles above Hsiao-hsin-kai. Limestone with a north 10° west strike was noticed cropping out at intervals the whole way. The mountain itself is over 6,800 feet high, and there are numerous portals of old tunnels and the remains of broken-down furnaces near the foot. Two levels were being worked; the lower sloped steeply in to the east. No more stone had been

taken out than was necessary to make a low road, but the roof, which was not a safe one, was very well timbered. The country rock was a hard, crystalline limestone, with a very micaceous and decomposed igneous (?) rock in small quantities. The ore body was met with about 120 feet in from the portal. It was about 15 feet in width at the face which was about 8 feet high. Its limits on either side were not seen.

A second level, some distance above the first, on the mountain side, met the ore-body about 30 feet in from the portal. Its limits were not visible.

On the top of the mountain, over 200 feet (by aneroid) above the level of the lower adit, there is a large outcrop visible, of, presumably, the same ore-body. Adjoining the limestone on its west side, it continued about 20 or 30 yards in breadth to the steep side of the mountain, in an easterly direction roughly, where it could be seen cropping out some way down. In a north-south direction the outcrop could be traced roughly for over 120 yards.

The ore consists of iron pyrites, with small quantities of pyrrhotite and smaller amounts of chalcopyrite and galena. There is certainly a large quantity of it available and I should have liked to make a thorough examination of the occurrence; this I was not able to do. The Chinese miners plan their workings to obtain the largest amount of lead and copper ores.

On a hill to the west of Hsiao-hsin-kai a limestone was mined for the argentiferous galena it contained. I did not visit the locality. Argentiferous galena was also obtained from Long-su and Loo-shan-ting further up the valley. I consider that the Ming-kuan is rich in minerals and that it is a field which holds out much promise to the prospector.

Silver content of certain ores from Ming-kuan.

Locality.	Ore.	Silver per ton of lead.
Tong-shan . . .	Galena . . .	156 oz. 2 dwts. 22 grs.; traces of gold.
Hong-too-hai . . .	Galena . . .	123 oz. 12 dwts. 20 grs.; appreciable traces of gold.
Hsiao-hsin-kai . . .	Slag . . .	6-34 metal, mainly copper, with a little lead.
		6 oz. 13 dwts. 22 grs. silver per ton of metal; traces of gold.
Hsiao-hsin-kai . . .	Lead . . .	18 oz. 18 dwts. 22 grs. silver; 3 dwts. 6 grs. gold.

(Analyst, T. R. Blyth, 1908).

As a comparison, the following assays of galena collected by Anderson in Yunnan may be quoted.

Ponsee . . .	Galena . . .	73 oz. 10 dwts.	. Analyst, A. Tween.
Kyet Yon . . .	" . . .	104 oz. 10 dwts.	. " "
Kakhyeen country .	" . . .	63 oz. 14 dwts.	. " "

The last specimen was collected by Dr. C. Williams somewhere in the Kachin Hills. It was analysed in 1863. The other two assays were performed in 1870. (A. Tween and T. R. Blyth were both officers of the Geological Survey of India).

Lead and Silver metallurgy in Western Yunnan.

The mining of galena by the Yunnanese is carried on under much the same rules as those adopted for other minerals. Some wealthy man or syndicate furnishes funds for the work and also supplies tools, lamps, clothes and food for the miners. They on their part are bound to sell him all the ore obtained. The financier does not interfere with the actual mining and the technical details of the operations are carried out by the men themselves. But he purchases the ores and is responsible for their transport away from the mine. Their subsequent treatment is carried out more under his immediate control, and smelting is performed by his own skilled workmen. He stands between the magistrate and the miner and pays the taxes and tribute demanded by the Government.

The ores from a group of workings are transported by mules or coolies to some central works, whose situation has been chosen with regard to distance from the mines, a plentiful supply of water for the washing of the ores and also in some cases for power to drive stamps and the turbine which operates the blower of the furnace. As the workmen often suffer from the furnace fumes, it is usual to build the latter in an open and well elevated spot, where the gases are dispersed as quickly as possible.

The ores are first hand-picked, at which the Chinese are very expert. The larger pieces are broken up by hammers. The richer ores are extracted as far as possible and are placed on one side, while the poorer material

and disseminated ore are carried to the stamps and washing-floor to be treated separately. As much of the gangue as can be removed is thrown away. The lean ores are usually crushed by hand, but mechanical devices are sometimes used. It is a custom in China as in most other Eastern countries to extract ore in the mines by heating the faces and then suddenly quenching them. This has the effect of rendering them more amenable to subsequent crushing than would be the case otherwise.

The stamp used is made on the same principle as the ordinary Chinese overshot waterwheel used for husking rice. Two heavy bars of wood are let in at right angles into the axle on both sides of the wheel. They are so arranged that as the wheel revolves they strike alternately heavy wooden beams which are poised as levers, by being supported at about two-thirds of their length. The blow delivered on one end of the beam depresses it and lifts up the other end. To the latter end a pestle is attached, made of wood as in the case of a rice mill, but fitted with a heavy iron shoe when stone is to be crushed. The pestle falls into a mortar in which the pieces of ore are placed. A strong stream of water carried in a box to the wheel serves to drive this rough but none the less useful machine.

The washing and concentration of the roughly powered ores is performed by the following processes. A stream of water is directed along a gently inclined wooden sluice-box some 12 feet long, 2 feet broad at one end and about 1 foot deep; it narrows slightly at the other end and has a removable riffle a few inches high. Beyond the box the water flows into a series of settling tanks. After placing the crushed ores in the box, the water is directed on to them and concentration done by a workman with a rake in the usual way. Fines escape into the tanks, which are cleaned up and their concentrates worked out from time to time.

A fairly high-grade lead ore is obtained by these methods, for no hesitation is shown in rejecting material showing any metallic impurities which would interfere with the subsequent smelting. Copper, antimony and zinc ores are removed in the hand-picking, gangue is removed by washing. The fact that the methods employed in lead-smelting vary little from place to place even over widely separated areas, although the association of other minerals with the lead ores alters

much in different localities, is sufficient to show that considerable care is taken in the preliminary concentrating processes. The Chinese profess to be able to tell from the lustre and structure of a particular galena, whether its silver content is high, low or medium. The ores of a fine granular appearance, compact and massive, and exhibiting glittering facets on the broken surface of a fractured specimen are considered to be the richest in silver.

Lead is usually produced in Yunnan by a "roast and reduction" method, but the Chinese are also acquainted with a "roast and reaction" method too. I have not seen this method in actual operation in Yunnan but it was employed on a very large scale at the Bawdwin mines of the Northern Shan States, as the remains of the old furnaces and composition of the slags proved.

The powdered ores are burnt in stalls, which consist simply of three brick walls, forming the three sides of a square four or five feet across, the fourth side being left open. Several of these are arranged in a row. The ore is stacked on a charcoal bed and alternate layers of ore and charcoal are added. After ignition, the mixture is allowed to burn slowly for several days, charcoal or even wood being added to keep combustion going as required. During this roasting the material agglomerates and when cool it has a porous, sintered appearance. If the ores have not been carefully selected, it is the custom to smash up the roasted mass and to concentrate it in the sluice-boxes already described. The operation of roasting is repeated four times, at the end of which most of the lead compounds appear to be in the form of oxides. Careful attention is paid to the ventilation and temperature of the roasting so as to prevent the formation of sulphates as far as possible and to obviate reduction to metallic lead.

The furnace used for smelting lead ores is from seven to nine feet high, made of brickwork and lined with a refractory material. The side walls vary greatly in thickness from place to place, but are always constructed in a massive manner so as to allow of the escape of as little heat as possible. The well of the furnace is roughly square in section with the corners rounded off, but it swells out into a funnel shape towards the top, to permit of easy charging. I have always seen charging done from the top of the furnace and not from a special door as described by some writers. The outer wall is roughly semi-circular in section and the back and

sides are sometimes built to project slightly above the front in order that the gases may be directed away from the charging floor and blower at the back. The front of the furnace is made of a double wall of brickwork which can be pulled out and renewed when necessary. It contains the slag hole, situated a little way above the depression which forms the hearth. The tapping hole is at the side of the furnace. Its clay plugging is pierced by means of an iron rod, and the molten metal flows into a mould in a bed of sand.

The blower is raised two or three feet above the level of the furnace hearth, and the tuyer is made to slope directly down upon the hearth. Great importance is attached to the direction given to the tuyer. The blower is of the ordinary cylindrical type about five or six feet long. It is worked by manual labour or by means of the upright-axed water wheel.

All the material put into the furnace is first weighed. To help the fusion at the commencement, a small quantity of old slag is sometimes added. The usual charge appears to be about two-thirds charcoal to one-third of ore, but of course there is no fixed rule and much depends on local conditions. Each group of furnaces is under the direction of one chief smelter, always an old man of great experience; beyond the careful regulation of the charges there does not appear to be any difficulty in working. The lead is cast into small pigs and is then sent to the cupellation furnace which is generally placed under a neighbouring shed.

The furnace, or as Rocher describes it, the oven, from its resemblance to a baker's oven, is generally of a hemispherical shape. (The Bawdwin furnaces were more of a beehive pattern than any I have seen in Yunnan.) Its diameter is between five and six feet, though I have seen larger furnaces than this, and the height is somewhat less. The hearth is only slightly concave and has a slight slope towards the door to permit of easy manipulation of the charge. Two doors in the wall which forms the front of the furnace serve, in the case of the lower as a charging door, and in the case of the upper as the door from which the firing is done. The most striking thing about the Chinese method is that the metal is placed under the fire and is heated by radiation from above. The section of the dome-shaped oven is semi-circular and at about half the distance up, that is to say between the level of the hearth and the

top of the dome, is placed the grating which supports the fire. The grating is made from a mixture of refractory sand with sufficient clay to keep it together. From the upper door the charcoal for firing can be placed on the grating. The dome is made of double brickwork and is lined with a refractory material. After the fire is lighted and the furnace well warmed, the lead to be cupelled is placed on the hearth, where it soon melts. A bridge of sand is built across the charging door to form a side for the bath of molten metal and to prevent it flowing out. The fire is kept going by the introduction of more charcoal, which has to be placed very carefully across the somewhat flimsy grating. As the temperature rises litharge commences to form, and when sufficient has accumulated it is removed by the introduction of an iron rod to which layer after layer of the litharge sticks as it is skimmed away. Sticks of stratified litharge, hollow down the centre are sometimes found on old Chinese slag heaps. I have come across them both at Bawdwin and in Yunnan. Nothing now remains but to keep the operation going by regulating the fire and removing the litharge as fast as it is formed. The process is a very tedious one and is prolonged sometimes for two days and nights. The silver which remains is far from pure and has to go through the hands of a refiner before it can be used as bullion. I understand that the Government insisted on a purity of 98 per cent. The litharge is either sold as such or is resmelted with charcoal in the ordinary way. Owing to the somewhat rough treatment which the furnace undergoes, there is nothing much left but the outside walls and it has to be practically rebuilt inside before another cupellation can be undertaken.

Rocher has described the refining of the silver, an operation

which I have not seen myself. The following notes are taken from his account of the process. The cake of silver from the cupel is sent to the refiner whose duty it is to bring it up to standard. The operation is done in an ordinary forge, the silver being melted in a crucible with powdered wood charcoal. As soon as the metal is molten, and the surface bubbles, two workmen are placed on each side of the forge and it is their duty to blow down long iron tubes on to the surface of the fused metal. Under the action of the oxygen the surface of the metal becomes covered with a layer of black oxidised scum, which is removed as soon as it is formed. During

the blowing the temperature decreases, the men therefore stop blowing, the fire is recharged and when the metal is fluid enough again, the blowing is recommenced. The master workman judges when the silver has reached the necessary standard of purity. The ingot moulds for the refined metal have various forms, sometimes oval for one or two taels of silver and rectangular for larger amounts.

Other localities.

Galena is mined on a very small scale on the hills at the eastern extremity of the Pu-piao valley, Yung-ch'ang Fu prefecture (lat. $25^{\circ} 6'$: long. $99^{\circ} 10'$). Sufficient ore was being won in 1909 to keep a small blast furnace and a cupel in operation. The ore seemed to occur in a narrow vein in Permo-Carboniferous limestone and was worked by an adit driven into the hill-side.

In Ch'eng-kung Hsien (lat. $24^{\circ} 53'$: long. $102^{\circ} 50'$) I was shown specimens of galena which were said to come from Yang-wan-shan, a locality in the hilly country to the south-west of the city.

In Ching-tung T'ing (lat. $24^{\circ} 26'$: long. $100^{\circ} 53'$) I saw poor specimens of galena reported as coming from the Chang-sa region.

The two following mines are said to produce silver in the Yungpei T'ing district:—P'ei-nin-ch'ang and Erh-p'ing-ch'ang.

In the prefecture of Li-chiang Fu, the mine of Lo-mi-cha is said to produce silver.

In a side valley at the head of the Mong-lai plain, passed by the road descending from Pang-wa in the Yun Chou district, there is an old lead mine. It was being worked in 1908, but I could not reach it owing to an unfordable stream. The mine is not a large one.

In the Chinese Shan States of Keng-ma and M'eng-hsa, on the Kunlon ferry route to Yun Chou, there are said to be three large lead mines which were abandoned eighty or ninety years ago. Great quantities of slag are said to exist near them and specimens were shown to me by the Shans. In appearance these slags were indistinguishable from those of Bawdwin. The two mines in Keng-ma are called Man-pien-ch'ang and Herh-shan-ch'ang. The one in M'eng-hsa is said to be only six li from the town of

the same name and is called Man-lao-ch'ang ("village of the old mine").

I saw good specimens of galena at Lao-pang-tung in the Shunning Fu prefecture where twenty men were employed in mining in 1909.

ZINC.

Zinc ores are an almost invariable associate of lead sulphide ores in Yunnan, and many of the localities where they occur have already been enumerated in the notes dealing with lead. The chief use of the metal in China is as an alloy in the coinage of cash. I have not seen zinc-smelting carried on and as far as I am aware the ores are not reduced in the western or central parts of the province. Zinc ores are said to be mined and smelted to the north of Hui-li-Chou in Ssu-ch'uan, but the most important centre is at Wei-ning Chou, just within the borders of Kuei-chou. The following notes on the treatment of zinc ores at Ma-lou-kio in this district are taken from the account of Duclos, who visited the region in 1896. (Du., pp. 298-299).

The zinc smelters at Ma-lou-kio are very primitive and do not need a large capital expenditure at first; their production is proportionately small; nevertheless the procedure followed is absolutely identical with "Vieille Montagne" practice. In this connection Duclos draws attention to the numerous inventions of the Chinese for which Europe believes herself privileged. But he also points out that such inventions have not been perfected. The routine which has preserved them has not been able to develop them.

The situation of the smelters at Ma-lou-kio, instead of at Tchatschang, where the mineral is obtained, is explained by the occurrence of coal on the flanks of the valley which surrounds the former place and by the fact that the operations require a large amount of fuel. On the other hand, the crucibles in which the ore is reduced, and of which great numbers are used, are made at Ma-lou-kio from a clay which is very abundant in the formations above the coal horizon. The first smelter visited had only half its furnaces in operation. The furnace is very simple and consists of an outer case with parallel walls about 12 metres long, 80 cms. in breadth and 1 metre in height. Small holes through the bottom serve for removing ashes. Transverse partitions divide

the outer case into compartments so arranged that separate parts of the furnace can be operated independently. About 60 crucibles are placed in the middle of the fuel (which is worked up with clay), and are arranged in three tiers. Each crucible has a pointed shape and measures 40 cms. long by 10 cms. in diameter at the open extremity, the wall is about 1 cm. thick. The pulverised ore is mixed with wood charcoal and charged in the bottom. The mixture is covered with a plug of clay, in which a kind of siphon is arranged to allow the zinc vapour to distill off. The upper part of the clay plug forms a basin-shaped space in which the vapours condense; to prevent their escape, the crucible is provided with a little clay lid. The crucibles cost from 12 to 13 cash each and are used for two operations. Two charges are made every 24 hours. The charge for 60 crucibles consists of 300 pounds of wood charcoal costing 2 cash per pound, and 200 pounds of ore costing on an average eight cash per pound. The production from one crucible is 5 ozs. The total production of one furnace is approximately 40 pounds of zinc in 24 hours. Three men are employed in each shift and they receive 100 cash each per day. The crucibles are made in the village in the same way as ordinary pottery. Most of the houses in the village are built with the remains of old crucibles.

Future of Lead, Silver and Zinc mining.

The fall in the price of silver is held by some authorities to have been the chief reason for the decline of the lead and silver industry in Yunnan. If this is read with the causes we have already advanced in the case of the copper mines, such as the general economic paralysis brought about by the rebellion, the rigorous official control, the exhaustion of easily won surface ores and the want of abundant fuel supplies, a greater measure of truth is probably arrived at.

Davies has given the price paid by the Chinese Government for copper about the year 1895 as 11 taels for 100 catties, or about three pence per pound, while zinc was being sold then at about one penny per pound. Davies believed that this was not enough to make mining pay and wondered how the cash which is the only real coin existing over the greater part of China, could be coined at less cost than its value as money. Where the prices of metals are

so low and the margin of profit on metallurgical operations so meagre, any great and permanent decrease in price is bound to result in the rapid decay and final extinction of these industries.

That modern European mining and metallurgical methods can be successfully applied to ancient Chinese mines is proved by the operations of the Burma Mines Co., Ltd., at Bawdwin in the Northern Shan States of Burma, and in China itself by the not inconsiderable quantities of mixed zinc-lead sulphides which were exported annually to Germany before the war. According to Ernest A. Smith :—"Lead-zinc sulphide deposits occur in Southern Hunan, but the important Sui-ku-shan mine worked by the Hunan Board of Mines, is the only one in the district in active operation. The ore is argentiferous galena, associated with blende, iron pyrites and calcite. A considerable proportion of the ore mined is dressed at the mine. The dressed blende and the mixed lead-zinc sulphides are sold to the German firm of Carlowitz and Co., having an ore-dressing plant at Woo-ch'ang, where the material is further separated, previous to exporting it to Germany to be smelted." ("The Development of the Spelter Industry," *Mining Journal*, September 30th, 1916, p. 666).

The mixed sulphide deposits of the Ming-kuan and the reported occurrences of extended ore deposits in Keng-ma and Mêng-hsa, are within comparatively short distances of the Burma frontier in the regions of Myitkyina and Kunlon ferry, respectively. Their existence should not be lost sight of in this connection.

Whether the deposits of the far interior, such as those of the Wei-ning Chou neighbourhood on the eastern borders of Yunnan will ever be exploited on a large scale would seem to depend more on the future development of communications in the province than on anything else.

TIN.

The famous cassiterite deposits of Ko-chiu in the Mêng-tzu region of Southern Yunnan have been mentioned by most of the writers on the province. Few Europeans have ever been allowed to study the underground workings. I have not visited the district myself and the following accounts are taken from the writings of Leclère, Deprat and Collins. (W. F. Collins, "Tin Production in the Province of Yunnan, China," *Trans. Inst. Min. and Met.*, Vol. XIX, pp. 187-211.)

These mines and their associated smelters form the most successful mineral enterprise in Yunnan at the present time.

According to Leclère, the deposits are found at altitudes of 2,000 to 2,700 metres above sea-level in the mountains between Mêng-tzu, Lin-an Fu and the Red River. The deposits are not entirely alluvial; they are obviously vein deposits. The cassiterite is always enclosed in a red clay, sometimes found in fissures of the limestone, at other times in the soil near them. The mineral is derived from the denudation of the upper portions of ancient lodes. As exploitation goes deeper, foreign metals appear and finally predominate, at first as oxides and later as sulphides. The deposits owe their origin to the tourmaline pegmatites which are injected through the lower strata up to the Lower Trias limestones. It is, however, worth noting that even in the upper deposits occurring in the midst of porphyries, analysis shows the presence of considerable amounts of tin.

At the time of Rocher's visit in 1872, silver, copper, zinc and iron were being worked as well as tin, but all the others have long since ceased to be produced, perhaps owing to the increased cost of fuel.

When Mr. W. F. Collins visited the region about 30,000 men were engaged in the mining, concentration and smelting of the ore; this was all reduced locally, and the metal exported to Hong Kong *via* Ton-king, and thence, after refining, the greater part passed to Europe. The deposits then worked were all of alluvial origin, and the mines, some 150 in number were scattered over an area about 25 miles long by 20 miles broad. The ore, usually of sand-grain size, was found in highly ferruginous bedded deposits. The underground ores generally contained a little magnetite and as much as 55 per cent. of hematite together with small percentages of lead. The deeper alluvial deposits were worked from inclined tunnels through the upper layers. Mr. Collins described the local methods of mining, dressing and concentration in detail.

Deprat believes it is unlikely that other tinstone deposits will be found in Eastern Yunnan outside the Red River region, as the geological formations are not favourable. I hold similar views regarding those parts of Western and Central Yunnan that I have traversed.

ARSENIC.

The following table gives the production of metallic tin in Yunnan from 1891 to 1908 :—

Year.	Long Tons.
1891	1,741
1892	2,063
1893	1,923
1894	2,343
1895	2,423
1896	2,013
1897	2,476
1898	2,733
1899	2,568
1900	2,898
1901	3,062
1902	3,788
1903	2,443
1904	2,979
1905	4,463
1906	3,984
1907	3,480
1908	4,558

Davies states that tin is found in the Tung-ch'uan Fu prefecture and probably in other places, but he gives no authority for the statement which requires confirmation. (D., p. 314) :—

ORPIMENT.

The importation into Burma, from Yunnan, of orpiment, the trisulphide of arsenic, has been going on for a considerable number of years. The mineral is mentioned by those early writers who visited Upper Burma long before the annexation of the country and later still by Clement Williams (Resident at the Court of Mandalay), and Anderson (Naturalist to Sladen's and Browne's missions), in their respective works. Of later years the traffic in the ore has increased and the traveller by the main trade route cannot fail to be struck by the number of mule caravans met with, laden solely with orpiment, and carrying it down from Western Yunnan to Bhamo, whence it reaches Mandalay and Rangoon. Owing, however, to the inaccessibility of the country, and to the secrecy of the merchants engaged in the trade, no one, as far as I am aware, has ever discovered the exact locality whence the ores are obtained, nor have the mines ever been visited by a European before. In my earlier attempts to reach the mines I encountered some opposi-

tion, but at a later date I succeeded in persuading the syndicate of owners to permit me to inspect them.

The orpiment mines lie at the head of a narrow ravine, 8,100 feet above the level of the sea. The ravine runs in a north and south direction, and is formed by a small stream which may be a tributary of the Yangpi Ho, itself an affluent of the Mekong. The journey can be made in two days from Hsia-kuan, going roughly to the south-west, and in three days from Ta-li Fu. The route followed at first is the main southerly trade route to Mêng-hua Ting, and Ch'ing-tung T'ing. This route is left at the pass (7,900 feet) over the mountain range about four miles to the south of Hsia-kuan, and one has to continue along a rough track which skirts a south-westerly striking range, which here appears to form the water-parting between the Mekong and the Red River. Except for small isolated communities of Lolo tribes, the country passed through is uninhabited and consists of bleak, sparsely wooded mountains. Food for man and beast has to be carried by the traveller. The mining district borders on an unsurveyed part of Yunnan and the sketchy nature of the map does not give a proper idea of the true topography. My own geological observations were hampered for this reason, and also by the inclemency of the weather. Blinding snow storms swept the face of the country during my journey and stay, and this, with the intense cold, made outdoor work a matter of some difficulty.

The rocks in the immediate vicinity of the mines, consist of reddish, reddish-purple and hard, greyish, quartzitic sandstones with black bands in places and reddish nodular shales. The strike is north-north-west and south-south-east, and the dip is at variable but high angles to the east-north-east. Probably these rocks are associated with the Red Beds series.

During the rise of the Mahomedan influence in Yunnan, the mines are said to have been worked by the rebel powers centred in Tali Fu. Since the fall of that city and the crushing of the Mussalman authority, they have been entirely controlled by the Chinese. Mineral was being won from seven drifts, which entered the hill on the north-east side and proceeded down as steep inclines until the ore-bearing stratum was reached. One drift was owned by local Lolos, who were compelled to sell the ore to the Chinese merchants who owned

the others. A royalty equivalent to Rs. 75 per annum was paid to the Government for each excavation. The workings that I was allowed to examine had been made with thoroughness and care. The roof, sides and floor of the inclines were very well timbered, and, sloping very steeply, had been constructed with steps to facilitate ascent and descent, while for 8 or 10 feet in every 100 feet they are driven straight. On these level places sumps are dug, into which the water drains and being ladled out is laboriously carried to the top in wooden buckets. Ventilation is quite good and is produced by driving rises through to the surface at various points. All the actual mining work was done by Lolos. Very few men were employed as ore was plentiful and easy to win. Their average wages worked out at about Rs. 3-8 to Rs. 4 per month; food was supplied by the owners. None of the drifts that I examined were very extensive, and were certainly not longer than 600 to 1,000 feet from the surface to the end.

The deposit appeared to be confined to one particular band of greyish quartzite, associated in places with soft, blackish shales. The whole of the former band was more or less mineralised. There was no distinct vein or single fracture. A thorough shattering of the rock seemed to have taken place, and orpiment to have been deposited in the bedding, joint and fracture planes, and also to have replaced the minerals of the rock itself to some extent. Small quantities of realgar occur and minute cubes of iron pyrites were also found. The arsenic sulphides were seen in irregular strings, swelling out into patches and bands, which sometimes attained a thickness of over twelve inches; these larger lumps however do not persist very far, but only continue for a short distance when they are replaced by others. The mineralised band was about four feet thick; it may be much more, and I can express no opinion as to its lateral continuations which may be considerable. I have no opinion to offer on the origin of the ores.

All the work is done with hammer and chisel, the broken ore being carried to the surface in baskets by small boys. It is then cracked by hand and the richer portions picked out. Those pieces which cannot be so treated are roughly crushed, and the gangue separated by panning in small closely-woven bamboo baskets. There is a great waste of the finer disseminated ore by these methods: indeed it is surprising how much material was being rejected by the Chinese.

The waste heaps must contain very large quantities of mineral, which could be easily recovered by means of a simple concentrating plant. Most of the orpiment is exported to Burma by mule caravan, though a little, with the realgar, is kept for local sale. The following table shows the importation of orpiment into Burma from Yunnan during the period 1895-96 to 1911-12 :—

Year.										Weight.	Value.
										(wts.	Rs.
1911-12	.	.	.	.	.	.	.	.	.	5,383	66,705
1910-11	.	.	.	.	.	.	.	.	.	6,540	71,340
1909-10	.	.	.	.	.	.	.	.	.	10,710	1,61,925
1908-09	.	.	.	.	.	.	.	.	.
1907-08	.	.	.	.	.	.	.	.	.
1906-07	.	.	.	.	.	.	.	.	.	8,095	1,49,022
1905-06	.	.	.	.	.	.	.	.	.	6,663	1,20,024
1904-05	.	.	.	.	.	.	.	.	.	5,285	97,290
1903-04	.	.	.	.	.	.	.	.	.	5,678	99,160
1902-03	.	.	.	.	.	.	.	.	.	10,831	1,37,440
1901-02	.	.	.	.	.	.	.	.	.	17,268	3,17,925
1900-01	.	.	.	.	.	.	.	.	.	12,075	2,22,330
1899-00	.	.	.	.	.	.	.	.	.	8,712	1,73,730
1898-99	.	.	.	.	.	.	.	.	.	5,253	1,12,840
1897-98	.	.	.	.	.	.	.	.	.	3,165	68,005
1896-97	.	.	.	.	.	.	.	.	.	3,779	81,165
1895-96	.	.	.	.	.	.	.	.	.	4,067	87,366

GOLD.

Previous Observers.

“Proceeding five days’ journey in a westerly direction from Karayan,” wrote Marco Polo in the thirteenth century, “you enter the province of Kardan-

Marco Polo.

dan, belonging to the dominion of the grant khan, and of which the principal city is named Vochang." (This place is believed to have been the modern Yung-ch'ang Fu). "The currency of this country is gold by weight, and also the porcelain shells, an ounce of gold is exchanged for five ounces of silver, and a *saggio* of gold for five *saggi* of silver; there being no silver mines in this country but much gold; and consequently the merchants who import silver obtain a large profit. Both the men and women of this province have the custom of covering their teeth with thin plates of gold, which are fitted with great nicety to the shape of the teeth, and remain on them continually." (Travels of Marco Polo, Dent's Edition, 1914, p. 249).

It is unquestionable that there is a certain amount of truth in the statements of the old Venetian as to the occurrence of gold in Yunnan. At the same time it is unfortunate that they have given rise to the exaggerated notions regarding the auriferous riches of Yunnan which have existed from the middle ages down to the present day. Gold dust has always been an export from Yunnan; quills of it can be purchased at the present time about the frontier towns of Burma. There is a gold-beating industry in Ta-li Fu and Yunnanese gold leaf probably gilded many of the older pagodas of Burma. Yet these facts do not warrant the belief that Yunnan is a potential Rand and it will be shown later that there is only one lode mine in the province itself and that most of the production, whatever its total annual amount may be, comes from a multitude of small placer workings, operated spasmodically by the poorer inhabitants of the country along the banks of the great rivers.

These Chinese authors in their monumental treatise, the "Tien Nan-Kuang-Chang," written about 1850, list the following four gold mines, the total annual taxes collected from which, according to Garnier were equal to 1,140 grams of gold, which, as he adds, does not give one high ideas of the gold production of the province. (G., p. 230).

- (1) Ma-kou, situated to the south-west of the Ouen mountain on the borders of Yunnan and in the district of Lin-an Fu. As the mine was taxed for each gang of gold washers, it was doubtless a placer deposit.

- (2) Kin-sha-chiang, to the south-west of Yung-peï T'ing, on the borders of the river. This locality was also taxed on the same basis as Ma-kou. It appears to me to include the workings along the Yangtze in this district where gold washing is still actively carried on.
- (3) Ma-kang, situated to the south of Tchong-tien.
- (4) Houang-tsao-pa, to the west of Têng-yüeh: "west of this mine is the Ta-in-kiang which flows through the territory of a chief." As this mine only yielded 1.4 per cent. of the total dues collected from the gold mines of the province about 1850, it is evident that its operations were conducted on a very small scale. The Ta-in-chiang is probably the Tai-ping which flows through the territories of the Shan chiefs of Kan-ngai and Nantien. No gold washing is done in this stream at the present day though a small amount is carried on in the terrace gravels of the upper Shweli to the north of Têng-yüeh.

In the Chinese annals of the Têng-yüeh and Yung chang Fu districts the date of which is not known, it is stated that gold mining is prohibited. The Chinese annals of Têng-yüeh. four following localities are mentioned however:

Lung-ling Lu-chiang, Chin-lung-ching, Leng-shui-ching, Kwai-kê.

The Lu-chiang is the Shwe-li of Burma. The other localities were probably placer workings in its tributaries.

Joubert states that all the rivers of Yunnan and Ssu-ch'uan carry gold, that the Yangtze in this part of its course, is called the Kin-cha-kiang or "River of Golden Sands," because of the abundance of the precious metal found in it. The statement that all the rivers of the country carry gold must not be taken too literally. It is an over-estimation comparable with the term "Old California" given by the same writer to this part of China (G., II, p. 161).

Joubert briefly describes gold-washing operations in the river of Lao-oua-tan, near Long-ki. On modern maps the town is Lao-wa-t'an on the Hêng-chiang, a tributary of the Yang-tze, in the extreme north-east corner of Yunnan. Here, in 1868, according to Joubert, there was an extensive deposit carrying gold and

silver in a small tributary of the Hêng-chiang. Each year from December to April, 2,000 or 3,000 men were employed in the workings. These were so far below the bed of the stream that 1,200 workmen were employed in de-watering operations by means of bamboo pumps.

In 1915 Professor J. A. T. Robertson who holds the chair of mining in the Technical College at Cheng-tu passed through Lao-wa-tan but he does not mention gold workings as existing there- (*Mining Magazine*, Nov. 1916, p. 271).

Missionaries informed Joubert that gold and copper mines existed at Tè-kô-tchang, 7 days' journey to the west of Ta-li Fu, and that extremely rich mines were worked near the borders of Yunnan and Kuei-chou, 10 stages south of Soui-tcheou Fu.

It is curious that this gold mine which is still producing, is not mentioned in the *Tien-nan-kuang-chang*. It has ever been published regarding it, and as the mine is the only lode mine in the province proper, I give a translation of his notes below. T'a-lang T'ing is a small city in the south of the province on the main route between P'u-erh Fu and the capital.

Joubert's account of the T'a-lang T'ing gold mines.

was visited by Joubert in 1867 and as his account appears to be the only one which

"Towards the north of the town, there is a portion of a mountain chain running east and west, slightly more elevated than the rest, on the top of which a village is situated, the population of which is entirely composed of miners exclusively occupied in the extraction of gold and silver. The village is about 1,700 or 1,800 metres above sea-level, and about 18 kilometres N 10° E from T'a-lang.

"At the base and on the flanks of the mountain a reddish sandstone is met with, very folded, altered and fractured; towards the top a compact limestone rises, slightly crystalline, traversed and raised by dykes of serpentine which crop out in the centre. This latter rock is widely distributed and crossed by narrow quartz veins, numerous in certain places. The part which is mined for the precious metals is centred around the village, but nevertheless covers a fairly large surface. The mountain is worked from the upper part and from both sides, but chiefly on its southern slope. This, having a very steep dip, offers most facility to the miners. The horizontal line over which mine openings and excavations can be seen on this slope is estimated at 4 kilometres.

It is impossible, from what we have observed, to come to an opinion on the value of the mines that we have visited; the community which works in them is a most wretched one, and nothing about it leads to a suspicion of much remuneration for its hard labour, but, on the other hand, the mining methods are so imperfect that the richest parts of the deposit might be missed.

The opinion of the inhabitants is that gold is abundant enough to yield good profits to those who seek for it; as for silver, it is not worth while collecting, if it is not mixed with gold. These two metals are in the native state and are irregularly dispersed in the serpentine in the form of lamellæ or very fine grains; they are found in a regular manner only in the interstices of the quartz veins or other rocks which cross or border the serpentine, and so these situations are particularly sought for by the miners. Silver is not associated with the gold everywhere, it is only found in a restricted area to the west of the village.

When the miner has chosen the place where he will carry on his work, he digs vertical pits, or level or inclined tunnels, according to the dip of the bed. Excavated material is scattered around the mouth of the working until the presence of the metal is recognised, then the working is carried in the direction of the gold-bearing vein. The earth and stones which are taken out are gathered up separately on a platform built near the opening of the working. It often happens that the first operations result in loss and work has to be abandoned after months of unsuccessful searching.

The materials extracted from the workings are reduced to powder and washed in a bamboo basket, really a form of rocker, which can be oscillated above an inclined wooden plane bearing transverse channels. The lighter portion of the materials is eliminated by this first washing; the sand, which is retained in a basin at the bottom of the inclined plane, and the contents of the grooves, are washed a second time in a small but very wide wooden bowl, of little depth and about 1 metre in diameter. A series of gyratory movements is given to this apparatus which permits the lighter substances to be washed away. This highly enriched secondary residue is treated with mercury, which on volatilisation, leaves a small button of gold at the bottom of the vessel.

The tools employed in mining are of the simplest kind; they comprise a hammer pointed at one end, and an iron chisel about

0.25 metres long. The hands perform the work of a shovel in gathering up the débris into a basket which a child carries out and empties.

"The most spacious workings which we saw did not measure more than 1 metre in height by 0.50 to 0.70 metres in breadth; very often when the rock is hard, or in a narrow place, the opening is only sufficient to allow the miner to pass. But apart from their narrowness the workings are generally well made and safe; the timbering is solid, joined together with split branches of pine which prevent falls from the roof or walls.

"Search for gold is not confined to the place we have just indicated. Descending from the mountain there are several torrents in which stone barricades retain the sands; these are washed and treated by the process already indicated.

"The inhabitants of the villages on the banks of the torrents descending from the mines adopt this method of work particularly; if it is not as lucrative as mining the ore deposits, it has the immense advantage of using up spare time, when the whole population is not absorbed in agricultural pursuits.

"400 or 500 men are actually employed at the mines, which are said to produce 50 or 60 taels of gold per month, which would be about 2 kilograms or 6,000 francs; it is safe to say that the work is irregular; the war which has desolated the province since 1855, has caused the miners and the numerous population grouped around the mines to disappear; the villages are abandoned and the houses overgrown by bushes. At an earlier period the revenue of the mines would have been about 1,000 taels per month, or more than 1,300,000 francs per annum. Nuggets are frequently found." (G. II, pp. 162-163).

According to Rocher (R., p. 247), deposits from which gold is

recovered are numerous in Yunnan; many were
Rocher (1880).

ruined by the rebellion, and only a few were working when he wrote. The treatment differs in nearly every mine; at T'a-lang a washing process is used; in the K'ai-hua prefecture, where veins occur in a very hard quartzitic rock, various washing operations have also given results. At Yung-pei, ground rich in gold is treated by amalgamation with mercury. A great number of streams carry gold, but not enough to warrant continuous work; nevertheless the people who live along the river banks, often wash the sands, with profitable results, during the dry season,

Leclère seems to have been very impressed with the auriferous riches of Yunnan. He writes as follows (Lc., Leclère (1897). pp. 445-46) :

"Gold mines are extremely numerous in the zone of the north and south folds, where, as we have seen, during the miocene period important movements were superposed on the earlier dislocations. The deposits noted in the Chinese lists extend as far south as the Laos, where they have been investigated by M. Marc Bel. (In this region the strike of the rich lodes appears to be perpendicular to the direction of the Red River). The quartz veins have only been opened up on the surface by native exploration. The only actual centre of gold-mining is T'a-lang T'ing near Ssü-mao. It was not visited, but information collected leaves no doubt about the richness in gold of the eastern borders of Tibet and Burma.

"This view is confirmed by the nature of the conglomerate terraces which are found over a hundred kilometres down stream from Ta-li where the Blue River (the Yangtze) is called the Kin-cha-kiang ("River of Golden Sands"). The amount of these conglomerates is very considerable, their thickness often attaining 100 metres. A detailed investigation would evidently be necessary to learn their actual values. There are about 500 gold-seekers scattered along the banks of the river. During the dry season they treat the sediments resulting from the re-washing of the banks. During the rainy season the industry is pursued on the upper parts of the terraces at the level of the rice fields. By their rudimentary methods they produce at least 1 or 2 decigrammes of gold per day."

According to Deprat (D., p. 246): "Gold mines are very numerous in the zone of the north and south folds of Ssü-ch'inese Tibet. The tributaries of the Yang-tze, such as the Ya-lung (Kin-Ho), come from this region, carrying gold-bearing sands which they drop into the Yangtze, it is from this cause that the rivers derive their names, Kin-hoo or "River of Gold" and Kin-cha-kiang or "River of Golden Sand." The gold is derived quite clearly from the basic rocks of the region, the diorites and diabases, and in this matter I share Leclère's opinion. It is probable that it also comes from the destruction of quartz veins which cross the Ya-lung. Whichever it may be, the gold is found in spangles in the recent river terraces of the Yangtze and even in the sands of its actual bed. (Leclère considers,

for some reason which I am ignorant of, that certain of these terraces are of miocene age. I have shown that the excavation of the Yangtze valley only commenced during the Quaternary). I have seen gold-washers at various places along the river, especially at Mo-lou-tchang; they are very wretched people and can hardly produce more than 2 decigrammes of gold per day. It would only be possible to obtain better results by using less rudimentary methods."

It is beyond question that the sands of the present river-beds and of the raised terraces in the upper courses of the Salween, Mekong and Yang-tze and their tributaries contain gold. Every traveller who has been in those parts of Yunnan has commented on the fact. Dr. Logan Jack in 1900 saw gold-washing between Wu-lu-t'ien and Wu-lu-pu villages on the Yangtze a few miles below Chi-t'ien which is about 25 miles east-north-east of Wei-hsi T'ing. He heard of mines and alluvial workings at Chin-sha on the Mekong, 30 miles north-west of the same city. A few miles above Shih-ku, which is situated at the Yang-tze bend, he saw 10 men washing for gold. (Logan Jack: "The Back Blocks of China," pp. 163, 171, 179).

Major Davies states that washing for gold is carried on in many parts of the upper Yangtze and its tributaries; that gold has always been an export from the country, chiefly in the form of gold leaf to gild the Burmese pagodas and that gold is an important article of trade at Tali Fu, where the gold-beating trade is carried on (D., pp. 314, 317, 67). He saw extensive gold-washing in a tributary of the Li-tang, itself an affluent of the Ya-lung between the town of Li-t'ang and a village named Ho-ch'u-k'a, one stage to the east. These places are in Ssü-chuanese Tibet, but belong to the same geological region. (D. p. 290).

Major Davies believes that the Mi-li country is probably rich in gold. It is situated in and about the junction of the Li-tang with the Ya-lung. The state seems to be entirely Tibetan and Mi-li itself, which is only about 20 miles beyond the Yunnan border, near the second bend of the Yangtze, is described as practically nothing but a big monastery inhabited almost entirely by lamas and by men who work for them. Major Davies and his party encountered a certain amount of opposition in entering the territory as the lamas thought they had come to prospect for gold,

The Swedish missionary Amundsen who was either the first or second European to visit the place, relates, according to Major Davies, that a few years ago some Chinese came to wash for gold in Mi-li territory, but the Tibetan inhabitants in their zeal for the preservation of the native industries, took the extreme protectionist measure of killing the intruders by rolling stones down the hill-side on them: "Now," Mr. Amundsen remarks, "none but Milians wash for gold."

In March 1900, Major Davies, either the second or third European to traverse this route, arrived at the Tibetan village of Ku-lu in the Mi-li state. He found the lamas very suspicious and goes on to relate that, "The next morning my interpreter went to the village to see about a guide, and was asked into the monastery by the head lama. He found that dignitary having an early breakfast and using a *gold plate* to eat off. Here was then the reason for the suspiciousness with which strangers are looked on in Mi-li. The country is probably rich in this metal and the Mi-li lamas are determined to keep it for themselves. 'What have you really come for? Have you not come to dig for gold?' was the first question the lama put." (D., pp. 239, 240).

Neither the Rev. Mr. Amundsen nor Major Davies are geologists or mining engineers, but their views have been confirmed by specialists like Mr. Herbert W. Gold in Mi-li. L. Way who, in June 1916, wrote, "From the Chien Chang valley through which flows the An Ning river on the east, to the Tibetan frontier on the west, and from Ta Chien Lu on the north to the Kin Sha river (or "river of golden sand") on the south, there is a stretch of country having an area of 40,000 square miles that is without doubt richer in mineral wealth than any other part of China, and one of the most highly mineralized spots in the whole world. This is a region of great disturbance geologically, and it is full of lodes and veins carrying gold and metallic ores. The streams and rivers contain many deposits of alluvial gold. Evidences of mining activity are seen on all sides, and mule trains are seen carrying copper metal and matte, lead bullion, iron, and other metals. The lodes are worked in a primitive way in the oxidized zones by the aboriginal tribes, some under the supervision of Chinamen. The sulphides are left behind as too refractory. The principal gold mine worked by the Lolos under the Imperial Government and Merchants of Szechuan is the Maha. This contains a wide

lode varying from 10 feet to 50 and 100 feet. The richer ore-shoots average 12 or 14 dwt. of gold per ton, and carry considerable silver, copper, and lead, and the lode from end to end averages 6 dwt. The ore has only been worked for about 20 years, but alluvial gold has been washed from time immemorial by sometimes as many as 15,000 men at a time, both in the valley in which the mine is situated, and in the sands and gravel bars of the Ya Lung river, 4,000 feet below the present workings. There are extensive native workings on a lode that outcrops beyond the Maha mine on the next mountain, but there the oxidation has not gone so far, and most of the ore is too refractory for the primitive methods of the Lolos, who throw the sulphides, chiefly pyrite, galena, and chalcocopyrite, on the dump. The ore selected for crushing is carried by hand over the summit of the ridge to the Ko Lo Lo creek 400 feet below, where there are 80 stamps worked by 40 overshot water-wheels. Each stamp weighs about 40 lbs. and crushes 60 lbs. of ore daily in a stone mortar. About 50 per cent. of the gold content of the ore is saved by means of quicksilver, which is obtained from a cinnabar mine situated at Hang Cho to the south of Kwa Pit. The amalgam is taken to the mining Bureau at Shaa Ba, where the miners are paid half its value, as they work on a 50 per cent. royalty. The workings are quite free from water, and as the lode dips with the slope of the mountain, the mine can be worked by adits to a great depth. A new cross-cut tunnel has recently been started, which should cut the vein 260 feet from its entrance. The workings on the Maha mine extend for 550 feet along the strike of the vein, and to a depth of 400 feet on its dip which is 35° from the vertical. The new adit should open up a large body of ore, and is expected to give at least 1,400 feet of backs below the outcrop." (*Mining Magazine*, July 1916, p. 22.) Other records in the same paper show a long list of known mineral occurrences including gold. It is only 40 or 50 miles as the crow flies from Maha to Ku-lu and a much shorter distance to the borders of Huang La-ma Tifang—the land of the Yellow Lama—as the Chinese call the kingdom of Mi-li. There are strong grounds for believing that the geological structure is much the same across the whole region and the fact that the Western portion of it is inhabited by a more or less independent race unfriendly to the Chinese, may well have prevented its mineral resources from becoming better known.

Personal Observations.

Native placer workings are carried on all along the Yunnan course of the Yang-tze. I have seen them myself around Chin-chiang-kai and from Ma-chang to the junction of the Ya-lung with the Yang-tze. At the former locality, which is only three stages north-east of Ta-li Fu, the gravels in the present river-bed were being washed by tribes-people, apparently in the employment of a local Chinese. An inclined riffled table of the usual pattern was being used and as the gravel was clean and the gold fairly coarse, it seemed to operate quite successfully. Further down stream the auriferous ground was being won from shallow drifts into the high-level alluvials. Around Hsin-kai and between it and the mouth of the Ya-lung, which appears to be a stream nearly as large as the Yangtze itself, the river terraces are pierced in many places by these old excavations. The treatment of the gold dust is the same in both localities. It is worked up with a tiny globule of mercury. The amalgam bead is placed in a little hole scooped out of a piece of smouldering cowdung. This is made to glow by being blown on through a narrow tube. The mercury evaporates and leaves a small sphere of gold.

I have crossed the valley of the Yung-p'ing Ho on several occasions. It is a tributary of the Mekong about half way between Yung-ch'ang Fu and Ta-li Fu. In this region I always heard rumours that the gravels of the stream contained gold and I tried panning in various places more than once, but met with no success. I do not know how the rumour has arisen, it is not probable that gold does occur in this valley, which is composed entirely of rocks of the Red Beds series.

A-lu-sh'ih is a small town situated about 20 miles north of Shun-ning Fu across the Mekong and on an unimportant route between that place and M'eng-hua-Ting. It has an elevation of 6,300 feet above sea-level, and is surrounded by metamorphic rocks, such as slates and phyllites, belonging to the Kao-liang system. This system is pierced a few miles further south, by the intrusive granites of the Shun-ning Fu neighbourhood. I was at A-lu-sh'ih in March, 1910, and found that gold-washing was being carried on in the deep valley of a small stream about a mile north of the town. This stream is a tributary of the He-Ho, itself a tributary

Reported occurrence
of gold in the Yung-
p'ing Ho.

Placer gold deposit
near A-lu-sh'ih.

of the Yang-pi Ho which, in its turn, joins the Mekong. I visited the workings which lie at an elevation of about 5,100 feet above sea-level or 1,200 feet below the town. There was a raised terrace deposit about 20 feet above stream-level, covered with terraced rice-fields and backed by the steep hill-side rising 800 or 900 feet above it. About 50 men were employed in digging out the pay-dirt from a number of holes in the terrace and washing it in sluice-boxes by the side of the stream. The gold obtained was coarse and did not appear to have travelled far. It probably comes from veins traversing the old slates in the vicinity. The deposit was not a large one, but it is interesting as showing another type of alluvial deposit distinct from the bigger ones in the rivers of northern Yunnan.

Regarding the future possibilities of alluvial or lode gold-mining in Yunnan or about its borders, all that can be said is that deposits exist which deserve careful testing. The Yang-tze, Mekong, Salween, Shwe-li and their tributaries all carry gold. In this they do not differ from the Irrawaddy and its branches, which may be regarded as members of the same great group of rivers as far as their upper reaches go. The Irrawaddy is the only one of the group in which long and careful tests have been made. Three gold-dredgers have worked for years on the Irrawaddy above Myitkyina and have recently (1918) ceased operations, which apparently cannot be carried on profitably. Whether the alluvial deposits of the other rivers are richer is unknown. The Chinese are the most frugal race in the world and too many earlier writers have been led to dream of El Dorados because they have seen a group of men eking out a miserable existence on lean gold deposits which no one else would touch. However, richer deposits may occur but they will have to be sought for and investigated.

The most promising region for the occurrence of lode gold appears to me to be in the basins of the Ya-lung and its tributary the Li-tang in Ssü-ch'uan.

SALT.

The salt-producing beds of Yunnan occur towards the base of the Red Beds series of Permo-Triassic age. This series covers a great expanse of country and the chief salt-manufacturing centres are situated in places where the lower horizons have been favour-

ably exposed. The following prefectures all contain districts from which salt is obtained and are arranged in order of relative importance :

1. Chu-hsuing Fu (lat. $25^{\circ} 0'$: long. $101^{\circ} 55'$): production 22,100 tons per annum from the districts of T'ing-Yüan Hsien, Yao-chou and Kuang-tung Hsien: supplies the districts around the capital and towns as far south as K'ai-hua Fu and Mêng-tzū Hsien, with an estimated population of 5,500,000 souls.

2. Pu-êrh Fu (lat. $23^{\circ} 5'$: long. $101^{\circ} 5'$): production 6,500 tons per annum from the districts of Chên yüan T'ing, Wei-yüan T'ing and Pu-êrh itself: supplies the south and south-western portions of the province, both Chinese and aboriginal, estimated in numbers at 1,625,000 souls.

3. Ta-li Fu (lat. $25^{\circ} 42'$: long. $100^{\circ} 10'$): production 3,600 tons per annum from the districts of Yün-lung Chou: supplies the towns of the Ta-li, Yung-ch'ang and Shun-ning prefectures, with an estimated population of 900,000 souls.

4. Li-chiang Fu (lat. $26^{\circ} 30'$: long. $100^{\circ} 10'$): production 1,400 tons per annum from the district of Ho-ch'ing Chou: supplies the north-western corner of the province, with an estimated population of 375,000 souls.

5. Ch'êng-chiang Fu (lat. $22^{\circ} 40'$: long. $102^{\circ} 55'$): production 1,300 tons per annum from the district of Ching-tung T'ing: supplies the surrounding country, which has an estimated population of 350,000 souls.

6. Yünnan Fu (lat. $25^{\circ} 0'$: long. $102^{\circ} 45'$): production 600 tons per annum, from the district of An-ning Chou: supplies certain areas to the south including Chiang-ch'uan Hsien and Hsin-hsing Chou, which have an estimated population of 150,000 souls.

7. Ch'u-ching Fu (lat. 25° : long. $103^{\circ} 44'$): production 400 tons per annum, from the district of Wu-t'ing Chou: supplies the country around Wu-t'ing Chou, which has an estimated population of 100,000 souls.

This grouping follows more or less approximately that adopted by the provincial Salt Administration. For our purposes it is better to adopt a broader classification based on geological and geographical considerations. (It may be noted first of all that all the salt-producing districts are east of the Mekong river). This can be done as follows:—

1. The salt-fields of North-Western Yunnan, including those of the Ta-li Fu and Li-chiang Fu prefectures.

2. The salt-fields of Central Yunnan, including those of the Ch'u-hsüing Fu, Yunnan Fu and Ch'u-ching Fu prefectures.

3. The salt-fields of South-Western Yunnan including those of the Pu-êrh Fu and Chêng-chiang Fu prefectures. The salt-fields of the Ching-tung district are situated about midway between those of Wei-yüan T'ing and Ting-yüan Hsien, but they are really an isolated portion of the south-western field.

The figures of production in the above list are calculated in short tons from Chinese statistics supplied to me in 1909 by Mr. Archibald Rose, at that time His Britannic Majesty's Consul in Têng-yüeh. It is not at all likely that the annual production of salt has varied very much since then. The total retail value of the 36,000 short tons of salt produced in Yunnan I calculate to be about Rs. 43,20,000 (£288,000) per annum, a price which compares favourably with that charged for the same commodity in the bazar of the Tavoy wolfram field at the moment of writing (June, 1918). Working from the same figures I calculated the total annual amount of revenue derived by the Government of that day from the manufacture and first sale of the salt to be Rs. 25,58,000 (£170,533), on the assumption that the prices and duties throughout the fields were the same as those in vogue in the north-western field.

It will be noticed that the 36,000 short tons of salt is consumed by a population of 9,000,000 souls, but it has been stated in the introduction to this work that the population of Yunnan is about 11,000,000 souls. The question may be asked, where do the remaining 2,000,000 people obtain their supplies from? In this connection it may be mentioned that the north-eastern districts of the province are supplied with salt from Ssü-ch'uan, that there are brine-wells at Ya-ka-lo, a town five miles outside the Yunnan border in the extreme north-western corner of the province, which according to Davies supply all the surrounding country (D., p. 263), and that there is a certain amount of illicit manufacture and contraband trade in salt in other regions.

Salt is also manufactured from brine at Yen-ching and Yen-tang in the Yen-yüan Hsien district of Ssü-ch'uan. Their places are within short distances of the northern border of Yunnan, in the Yung-pei T'ing district.

Salt in the Ting-Yuan Hsien district.

Although the existence of salt in the province of Yunnan has been known for a long time, no detailed account either of its occurrence, or of the important industry to which it has given rise, appears to have been recorded by any of the earlier travellers who have visited this particular district.

The salt industry of the Ting-yüan Hsien district. (Lat. 25° 20' long. 101° 31').

The salt wells are all situated in rocks belonging to the series, of probable Permo-Trias age, which attains such an enormous development in this part of Yunnan and to which I have given the name of the Red Bed series. It has proved quite unfossiliferous. In the neighbourhood of Ting-yüan Hsien, reddish and reddish-violet shales with thin quartzitic bands strike N.N.W.-S.S.E. and dip at from 45° to 50° in a westerly direction. Between this place and Lan-ching there are many exposures of red shales and further on in an easterly direction, hard red sandstones of considerable thickness are found dipping east.

Ting-yüan Hsien is a prosperous walled city of the fourth class, situated two stages to the north of C'hu-hsiung Fu, in the fertile plain of a tributary of the Tsoling Ho, itself a tributary of the Yang-tze Chiang. C'hu-hsiung Fu itself lies on the main trade route from Ta-li Fu to Yunnan Fu, the capital of the province, and is some eight stages from the former, and six stages from the latter city. From Ting-yüan Hsien a good road runs in a south-easterly direction, by which the main route may be rejoined after four stages at Lu-feng Hsien, three marches from Yunnan Fu.

The three localities, Lan-ching, Hei-ching and Hou-ching, at which salt is prepared, are situated along this road. (The termination "ching" means a well.)

Lan-ching is a large village situated at an altitude of 5,600 feet in the valley of a tributary of the Tsoling Ho, about eight miles to the east of Ting-yüan Hsien. The salt here is made entirely from the brine of five underground wells, all of which exist in the neighbourhood of the village. The two wells I have inspected are on the south side of the river, about half a mile to the west of Lan-ching.

The salt wells of Lan-ching.

A steep incline,—constructed with steps to facilitate ascent and descent,—usually about eight feet in height, six feet in breadth and some twenty or thirty yards long, is driven down into the salt-

bearing strata. At the bottom for a few feet it is carried along straight, and then terminates in a well with a diameter of five or six, and a depth of sixty or eighty feet.

The salt is dissolved out by the water in the rocks, and then, percolating into the well, is raised in a carrier made of untanned buffalo skin by means of a buffalo-hide rope, working on a primitive windlass manipulated by four men. The windlass is a very crude arrangement, consisting simply of a round wooden axle, with two long pieces of wood dovetailed into each end at right angles to one another, to form the handles. The axle is supported on a pair of cross-stays, one on each side of the well. As there is no safety clutch and the carrier full of brine is very heavy, there is little protection for the workmen in case of accident.

On reaching the top of the well, the brine is emptied into a small auxiliary tank of no great depth, excavated out of the rock. From here it is pumped to the surface as occasion requires. The pumps are made of hollow bamboos, from four to six inches in diameter, and from eight to ten feet long, fitted with a piston made from a stick with a T-piece handle, to the other end of which a loosely fitting plunger of skin packed with straw, is attached. This is inserted inside the bamboo, which is open at both ends, and has one end dipping into the second brine-well. A man, sitting astride, fills the bamboo with brine by means of a hand baler and then quickly works the handle up and down; the brine is sucked up and flows out at the upper open end into a small pool built on the side of the incline. From this pool another pump of the same kind lifts the salt solution a little higher, and the operation is repeated until the surface is reached. The brine is now allowed to flow by gravitation in open wooden boxes, made by hollowing out tree trunks, to large wooden storage tanks generally sunk in the ground, and situated near the evaporating sheds. It is ladled from the tanks when wanted and carried in wooden pails constructed to fit on the necks of coolies by means of a shoulder-piece. The evaporating-sheds usually contain four furnaces, each of which is fitted with twenty to thirty hemispherical iron pans which vary from two to four feet in diameter. The pans are made of cast iron and are supported on iron bars covered with brickwork. The entire top of the furnace is filled in with clay and brickwork up to the level of the tops of the pans. The crude brine is systematically treated; going first into a large central pan,

it is heated and then filtered whilst hot, through linen which catches all insoluble impurities, into a second pan. As it becomes more concentrated, it is transferred again and again by means of a small wooden baler with a long bamboo handle, until solid cakes of salt are obtained. When the furnace, which is heated with fires of brushwood or pine needles, is cool, the salt is taken from the pans, cleaned and weighed. Alternate furnaces are worked on alternate days, so as to allow of repairs being effected. At intervals of a month or so, the brick and clay work of the furnace is replaced, the old material being broken up and leached with water to extract the salt with which it is impregnated. The life of the pans in this somewhat rough treatment is short, though to facilitate the extraction of the salt they are generally well oiled before boiling is commenced.

The monthly output of the five wells is said to average about 80,000 catties of salt per month, *i.e.*, 960,000 catties per annum.

One hundred catties of Lan-ching salt are sold for 3 taels 8 mace of silver.

These figures were given to me by the Salt Revenue Official of the Chinese Government in charge at Lan-ching.

Hei-ching is situated about six miles to the north-east of Lan-ching. The road after leaving the latter place, commences at once the ascent to a steep north and south ridge, which here forms the western boundary of the Tso'-ling Ho watershed. The crest of the ridge has an elevation of 7,300 feet, and there is a very steep descent down to the river at Hei-ching (5,500 feet).

Hei-ching and its
brine wells.

The small town is practically built around the brine-wells, which are situated along the bottom of the narrow valley, on the west side just above the level of the river. Eight wells, all of which appear to be in a massive red sandstone formation are producing brine at the present time. I have visited all these and found that although the majority are situated under-ground like those in Lan-ching, there are others here which are open to the surface. The brine is won and treated by methods exactly similar to those just described, though the industry, being much larger here, supports a greater number of men. The average pay of a coolie is from two and a half to three and a half taels per month and the pay of an overseer ten taels per mensem. The brushwood used for firing the furnaces is costly in comparison

with the prices in vogue in other parts of Yunnan. This is because it has to be brought long distances, the neighbouring hills having been absolutely denuded in past decades.

The Hei-ching, salt is cleaner and of better appearance than that prepared in Lan-ching, and it brings a higher price, viz., 4 taels 5 mace per 100 catties.

The present output is said to average roughly 600,000 catties of salt per month, i.e., 7,000,000 catties per annum.

Hou-ching is the most important of the salt-producing areas of this part of the province. The town lies twelve miles to the south-east of Hei-ching and is about three miles to the south of Hsiang-chi-shao on the main road from Ting-yüan Hsien to Yunnan Fu. There is a very steep climb out of the Hei-ching valley, and after this the route practically keeps to the top of a south-easterly-running spur, at a general elevation of 8,000 feet until Hsiang-chi-shao is passed. Thence a very precipitous descent brings one into the town, which is built in a very inaccessible position, and may be said to have sprung up around the mines, under the steep western slope of the valley of a small mountain stream.

There is very little cultivated ground in the neighbourhood, the population being mainly engaged in, or dependent in some way upon, the salt industry.

Hou-ching possesses several brine-wells of the same type as those already described, and also three mines from which rock-salt is won. Permission to visit one of the mines was granted me by the mandarin of the town.

The salt mine, allowing for the absence of modern appliances for drainage, ventilation, and haulage, is as good as any similar underground working in Europe. The entrance level commenced with a short upward, and then a gradually descending, slope for about 200 yards until the present "working district" was met with. The timbering could not be better; indeed quite unusual precautions are taken to hold up the roof and sides. The ventilation is excellent and is obtained by driving air-shafts through to the surface. From the lower end of the main level, galleries branch off in various directions; these are large and being arched, no timber is required in them. The salt occurs in patches and strings in a hard red sandstone of considerable, but unknown, thickness only about 20 feet of it being mined. This red salt-bearing sand-

stone is attacked in a methodical manner by driving large galleries into it, only sufficiently large "pillars" being left to keep up the arched roof of the working. It is customary for the miners to work in pairs; their tools consist of chisel and hammer, one man holding the short wedge-shaped chisel whilst the other man strikes with a heavy sledge-hammer. In this mine alone over 80 miners and more than 120 coolies find employment. Two miners can produce 25 coolies' loads per diem. The salt-bearing rock is carried out in oval buckets, fastened on the back of the coolie by means of a shoulder-piece, grooved for the neck, and a head band. The mine is singularly free from water; what little there is drains into a deep well and is thence raised to the surface by means of the usual bamboo pumps.

The rock containing the salt is smashed up and then leached with water, the brine so produced being boiled down in the usual manner.

Some of the furnaces in Hou-ching are much larger than those at the other places, and are constructed to take over 40 small pans. The salt in all the localities is taken to the Government stores after being cleaned and weighed. It is there officially stamped with red paint which, covering practically the whole surface, would instantly show any attempt at pilfering by breaking off salt from the larger pieces. From the stores it is distributed mainly to the capital, Yunnan Fu, but it is no uncommon occurrence to meet mule-trains on the roads far from this centre, engaged in the transportation of salt from the Ting-yüan Hsien district.

The output of the Hou-ching mines is said to be just over 1,000,000 catties per mensem, *i.e.*, 12,000,000 catties per annum. The price of salt here is the same as in Hei-ching, *viz.*, 4 taels 5 mace per 100 catties.

I am unable to go into the costs of working the salt mines and wells and to compare them with the returns for the salt produced, owing to the incompleteness of the data at my disposal, a consequence of the short time which I was able to devote to the investigation of the question. But from rough calculations and on the general impressions of my visit, I have no hesitation in saying that large profits are obtained by the Chinese Government from their salt manufacture.

Total output and value of salt from mines and wells.

To give some idea of the great extent to which this manufacture has grown I add the following numerical data. Whilst I have made every endeavour in my power to obtain correct figures, I cannot in any way guarantee them. They were given me entirely by the head officials, or their clerks, of the Salt Revenue Department in each place. (H. B. M. Consul-General in Yunnan Fu informed me that the mandarin in charge of the salt revenues of the whole province has the same rank as a territorial "Tao-tai," which shows the importance attached by the Chinese to the salt industry).

Locality.	Estimated output per annum.		Value in rupees.
	Catties.	Tons.	
Lan-ching	960,000	571	Rs. 88,975
Hei-ching	7,200,000	4,285	7,90,244
Hou-ching	12,000,000	7,143	13,17,073
TOTAL	201,600 (piculs)	11,999 (approx.)	21,96,292

NOTE.—The value is calculated on the retail spot price per 100 catties, and on the assumption that 100 catties=133½ lbs. avoirdupois.
41 taels=Rs. 100 (1908 exchange value).
Fractions of one ton are not included.

As salt is a monopoly of the Chinese Government, and also a source of revenue in the Indian Empire, questions are raised, in any discussion with regard to its trans-frontier carriage, which cannot be dealt with by a geologist. The supply of salt for Yunnan itself, with its large population, appears to be in no danger of exceeding the demand. One of the most serious expenses of the industry is the cost of transportation, from the manufacturing centres to the areas of distribution, which is at present carried on by coolie or by pack mules. The introduction of railways into the province will considerably reduce this expenditure.

There is a splendid opportunity for the introduction of European machinery into the salt wells and mines. Small pumps of no great cost working at the wells would effect great economy, whilst

the same end would be attained by installing a modern hauling plant in the various Hou-ching mines.

Salt in the Yün-lung Chou district.

Yün-lung Chou is a small unwallled city situated in latitude $25^{\circ} 48'$: longitude $99^{\circ} 18'$, at a height of 5,500 feet above the sea, in the Ta-li Fu prefecture, but under the immediate jurisdiction of a small civil official, the Chou-Kuan. The city is built in a narrow valley surrounded by steep, barren mountains so that there is little ground under cultivation. A small river, the Loma Ho, a tributary of the Mekong, flows down the valley and is crossed by a covered bridge. A weekly market is held, to which the inhabitants of the surrounding villages congregate; they are chiefly Minchia and Minchia-Chinese and have a very poverty-stricken appearance. The city appears to contain about 5,000 people, and owes its existence to the salt-wells in the environs. Though at the present time the city must be classified amongst the poorest in Yunnan, evidences are not wanting pointing to a former prosperity when the brine-wells were more productive.

I left Têngyüeh on 15th March 1909, and proceeded by the main easterly route as far as Yung-ping Hsien, a distance of 102 miles, which was reached on 22nd March. This is a small walled city situated in a plain formed by the Yung-ping Ho, a tributary of the Mekong. From Yung-ping Hsien the main road continues in a north-easterly direction to Hsia-Kuan and Ta-li Fu, whilst the route to Yün-lung Chou proceeds in a north-westerly direction from the city, which has an elevation of 5,300 feet.

The whole of the country on this side of the Mekong, between Yung-ping Hsien and Yün-lung Chou, is made up of rocks of the Red Beds series of Permo-Triassic age. There is reason to suppose that they also stretch for considerable distances into the unsurveyed areas to the north. Around Yung-ping Hsien, alluvial deposits of the valley plain were met with, consisting of yellow coarse-grained, friable sandstones, white, and brownish-white, fine-grained shales with fragmentary plant remains and broken indeterminate *Gasteropoda*. In places thin bands of lignitic carbonaceous shales were seen. The road continues up the valley of the Yung-ping Ho and after crossing the alluvial deposits, poor ex-

posures of red shales and sandstones were seen in the bed of the stream. The first stage is reached at Kuan-Chiao, 11 miles from the city.

For some miles beyond this village similar sandstones and shales are found in rapid alternations, the sandstones predominating on the whole. The general strike is about north 20° west and the dip 53° towards the south-west. It was very difficult to locate my exact position from the map hereabouts; the names of many of the villages shown are unknown to the local inhabitants, neither does the road follow the main stream as indicated. In reality it takes a northerly turn and ascends one of the tributary streams, crosses a small spur and continues up the side valley. Numberless blocks of red sandstone and shale strew the beds of the streams, whilst the steep forest-clad hillsides rise up very close to the water. There is now a very steep ascent to the top of the ridge separating the valleys of the Yung-ping Ho and Lo-ma Ho, at an elevation of 8,600 feet. From the summit an extensive view is obtained of the country to the north, including the Mekong valley, and the break in the hills where the Lo-ma Ho flows through to join its parent stream. The hills are all covered with thick forest, the monotonous tints of the pines and evergreens being brightened at the time of my journey by patches of scarlet and white rhododendron blooms. There is a steep descent to a small tributary of the Lo-ma Ho and after a slight rise the track proceeds north-west, keeping almost level high up above the bottom of the valley; passing through the scattered hamlets of Kan-hai-tzu and Po chiao, it then descends very precipitously to the river-bed and at 25 miles reaches the hamlet of Sha-chiao.

The country around this place is very poor, the villages are small and scattered, and it is almost impossible to obtain supplies or fodder. The people are all Minchia and Lolo, the pure Chinese type being conspicuous by its absence. Poppy cultivation and opium manufacture used to be the staple industry of these tribes, but the recent prohibition edicts have had a wonderful effect in banishing the poppy even from these remote valleys where it used to form the chief means of livelihood of the people. The Lo-ma Ho at Sha-chiao is a deep and unfordable stream with a strong current. Its bed is from 50 to 100 yards wide and is full of ~~granitic boulders~~. In places the water fills the bed, but in ~~the~~ swift rapids 15 to 20 yards across,

The bottom of the stream is rocky, its valley is deep and precipitous, but there are narrow bands of cultivation around Sha-chiao.

The Yün-lung Chou route continues in a northerly direction along this valley, reaching the city at mile 40 from Yung-ping Hsien. The valley narrows considerably and becomes gorge-like, and it is only at the bends that there are deposits of alluvial soil suitable for cultivation, and even these small fields are half covered with boulders which have fallen from the cliffs. There is much contortion of the strata near Hsi-fang, where an excellent example of a complex double fold is seen in a cliff section on the west bank. There are very few shale outcrops and the whole country seems to be chiefly made up of this greyish-red sandstone formation. The dip is variable but usually steep towards the north-east. The river is crossed at the small Minchia village of Sung-ma by a wooden roofed bridge, and above this place as far as Yün-lung Chou the road keeps to the west side; the valley however becomes very narrow again and just before the city is reached resource is had to step-cutting in the rocky sides in order to carry the road through. Falls of stone must be of frequent occurrence. Hard reddish sandstones and white fine-grained quartzitic sandstones crop out in this part of the valley.

I arrived in Yün-lung Chou on 25th March, which happened to be market day, so that large numbers of people were gathered together. The Minchia men are powerful and muscular and used to carrying heavy loads. Goitre is extremely common and even young children frequently exhibit the swollen glands in the neck. There is only one camping ground on the alluvial plain opposite the city. Hundreds of people assembled to watch the pitching of my tents, as foreign travellers are very rarely seen in these out-of-the-way regions. They were, however, a friendly though exceedingly dirty mob.

All the salt which the Yün-lung Chou district produces is manufactured from brine obtained from a number of wells situated in the vicinity. There are no salt mines.

Brine wells are found at:—

Pao-fung-ching—in the city itself.

Shih-men-ching

Tien-erh-ching

Ta-ching

Shang-ching

} —in a valley six miles north of the town,

Lo-ten-ching.	}	—in the unsurveyed area to the north of Yün-lung Chou.
Lu-ching.		
Shwun-tan-ching.		

An official of the Imperial Chinese Customs Service has recently written :—

“ If the collection of the land tax is veiled by obscurity, of the grain tribute by equal obscurity, of the salt gabelle in the “ Regular ” Customs by greater obscurity, the greatest obscurity covers the revenue from the salt gabelle, owing to the mixture of the official and mercantile elements in its collection. Salt is everywhere under the strictest Government control, and is taxed at every stage—in its manufacture, purchase, at the vats, transport, sale at the *dépôt*, and sale to the people.”

In Yünnan it is easy enough to see into the higher department of the salt gabelle, to understand the official relationships of the mandarins, who occupy the highest posts in the administration, but to come to a proper appreciation of the organization at the other end of the scale—which is vastly more important to understand in a discussion of this sort—the obligations of the brine-winners and salt-manufacturers themselves to the government, is often a difficult matter. So long as the smaller officials of the salt administration keep the peace in their respective areas, and regularly forward to the central bureau at the appointed times, the amounts of revenue for which they are assessed, the provincial government is not likely to concern itself very much in the dealings of its agents with the producers. It is therefore found that different systems of work are in operation in different districts, sometimes even at neighbouring wells in the same area. A local official will modify or alter the methods of working with the people in accordance with local tradition and custom, with the alteration of the assessments, with the price of fuel, or in any way to suit his pocket, being always careful enough to keep clear of conditions which would cause active opposition, for which he would certainly be held responsible by his superiors. Wells under a mandarin may be worked entirely by him, that is to say, he may supply the capital and take the risk, the actual workers being merely his servants ; or again, he may control a company (in the usual Chinese meaning of the word). Sometimes in the case of salt wells and mines the mandarins have no connection with the companies, which may

be composed of groups of capitalists or even of a whole municipality. Cases are known in which the miners and drillers work wells on a kind of co-operative basis. It is not safe to take any district or any well and set it up as a type of all others. Conditions which vary a great deal are also introduced in the systems of payments for evaporation of the brine and also in trading in the finished salt. These, coupled with the natural Chinese suspicion, exaggeration and unwillingness to give true information, often make the task of the investigator anything but a light one.

The highest official in the salt gabelle dealing with the Yün-lung Chou area is the "Yen-ta-shu" who resides at Tien-erh-ching and who is responsible for the collection of revenue in the whole of this district. He is subordinate to the "Yen-ti-ki" who resides in Pe-ching and is in charge of several salt-producing areas. Deputy officials or "Wei-yuans" of small rank are usually stationed at each well. It is their duty to keep accounts of brine extracted, and of the people who take it away for evaporation. Other minor officials are in charge at the weighing stations and storehouses.

Description of wells. Pao-fung-ching.	The Pao-fung-ching well is situated on the mountain side above the town of Yün-lung Chou,—indeed the town appears to have grown up round this brine well, which in former times was of some
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importance and yielded large quantities of salt. At present it is in an impoverished condition. The methods used by the Chinese in drilling the well and obtaining the brine are exactly the same as those in vogue in the Ting-yuan Hsien district of Central Yunnan, which I have already described in some detail. It is therefore unnecessary to recapitulate here. The brine is conducted down from the well to a storage tank in the middle of the town by open wooden water-boxes. The storage tanks are made of wood. From them the brine is baled out as required and taken away to be evaporated. A writer keeps an account of the various amounts taken away by different people. The brine is very weak and the output from this well has declined rapidly in recent years. The actual working is in the hands of a small company, who pay a license fee of 18 taels per mensem to the local official, to whom they are compelled to sell all the salt produced. There are only 10 coolies employed in carrying brine; they are paid at the rate of $\frac{1}{10}$ tael per day each. Most of the evaporation is

done in dwelling houses, the pans being arranged in batteries of 14. I estimate that there are about 30 batteries in Yün-lung Chou. The salt is of poor quality and is sold by the government at the rate of 3.6 taels per 100 catties.

The small town of Shih-men-ching lies six miles to the north-east of Yün-lung Chou, a good mule-track connecting the two places. After crossing the river, there is a steep ascent up the east bank as far as Shan-ting-tzu, whence a gradual descent brings the road almost down to the level of the water again at mile 2. On the opposite bank near this place a large hot spring issues from beneath a precipitous cliff of sandstone. Chinese and aborigines come from far and near to bathe in the waters, which are alleged to have curative properties in the treatment of skin diseases. After crossing a tributary stream by a substantial wooden bridge at mile 3, the road ascends and descends and in places is actually built up above the river-bed. The strike of the massive red sandstone veers round to the east and west and there is a dip of 17° to the north. The valley widens out where it receives a tributary coming from the east, the main stream continuing north. Shih-men-ching, a village of about 120 houses, is situated about half a mile up this tributary valley. Immediately to the north, stretching for at least 100 miles, is a large area of unsurveyed country which has never been seen by a European. There is not much land suitable for cultivation around Shih-men-ching, and the prosperity of the place has evidently declined in recent years. Numerous rock inscriptions, temples and memorial stones proclaim to the traveller that the village was the birthplace of a Chinese who rose to be governor of the province of Shan-si. This fact is blazoned forth on all sides, and in the eyes of the natives elevates their homestead far above the depressing level of the ordinary Yünnanese village.

The Shih-men-ching brine-well is at the eastern end of the village; it is best described as a twin well as there are two shafts close together. At the time of my visit only one was giving brine; sweet water was being pumped from the other. There are numerous shrines of patron deities around the well and storage tanks. Brine has been met with here without digging a shaft so that only a shallow drift is needed and the familiar windlass and untanned skin brine-carrier are absent, the salt water being

raised by four hand-worked bamboo pumps. The brine is of good quality and the total yield is said to be about 80,000 catties per mensem. The fiscal system of the Shih-men-ching well is somewhat complicated. Brine is won under the direction and control of the "Yen-ta-shu," but the people have to pay a monthly license of 64 taels to Government. This is an increase of 24 taels on the amount demanded for the license last year (1908), and is one little incident in the wholesale increase which the provincial mineral duties are being burdened with this year in order to find funds for the military, educational, and railway schemes of the late Viceroy. The contractors who undertake the evaporation of the brine have to find their own fuel and to pay for the carriage of the brine from the storage tanks to the evaporation sheds. Fuel is fairly cheap, as the unsurveyed areas to the north are full of forest and advantage is taken of the swift current of the Lo-ma Ho to float the logs down to the salt-producing places. Large numbers of coolies are engaged in carrying wood from the river to the yard whence it is retailed as required. Owing to deforestation in bygone days there is very little fuel in the immediate neighbourhood of these places. There are about 30 batteries of evaporating pans in Shih-men-ching, each consisting of batches of 12 or 14 pans. (On an average it takes three days for one battery to produce 100 catties of salt. The total production must be sent to the stores of the "Yen-ta-shu," who pays for it at the rate of Tls. .9 per 100 catties. The duty amounted to Tls. 2.35 per 100 catties and the local selling price is Tls. 4 per 100 catties. The local official is left therefore with a balance of Tls. $4 - (2.35 + .9) = \text{Tls. } .75$. Out of this he has to keep the wells in repair, pay the wages of pump-men and writers and meet all other incidental expenses. There is another small well to the east of the village, but its production is unimportant and I have classed it under Shih-men-ching.

Two miles further up the Shih-men-ching valley in an easterly direction, the village of Ta-ching is found.

It is a large place with about 120 houses, the inhabitants being mainly dependent for a livelihood on the salt-well situated just outside the village. There are very few rock exposures, but there is much scree and rock débris on the hillsides owing to the excessive denudation of the slopes. I made an inspection of the Ta-ching well and have never seen a better engineered

or cleaner kept underground excavation in Yünnan. The drifts going into the ground are very steep, their mouths being protected by stone-roofed buildings and the roads were carefully gated. For the first few yards the mouth of the main drift is arched, but beyond this it is supported by timber arranged in a systematic manner. The drift extends steeply down for 72 paces, when the brine is reached. Steps are constructed to facilitate ascent and descent. The brine is pumped out by the usual methods, the relay cisterns being of solid wood-work and not of clay, as is so often the case. Stone conduits take the brine to the storage tanks, which are well built and covered. Pumping is carried on in the evening and early morning, with an interval of rest during the greater part of the day.

The Ta-ching well produces 70,000 catties of salt per mensem, but it is not equal in quality to the Shih-men-ching salt and only brings Tls. 3·8 per 100 catties. The fiscal organization is the same as at Shih-men-ching, the mandarin buying in the salt at Tls. ·9 per 100 catties. There are 30 batteries of evaporating pans in the village. I observed here a curious method of finishing the salt which is not adopted on the other salt-fields of Yünnan as far as I know. Generally, the brine is evaporated and the salt dried in the pan, fresh liquor being added from time to time until a solid hemispherical mass of salt—the cast of the pan—is obtained. At Ta-ching and other places in this valley, however, the salt is removed from the pan when it is still wet, and firmly pressed into small cylindrical moulds, so that instead of the large masses made on the other salt fields, which form a heavy load for a man, the salt comes on to the market in the shape of small cylinders each of about 3 lbs. or so in weight.

The large village of Tien-erh-ching is built on the steep northern slopes two miles further up the valley.

Tien-erh-ching. There are here good exposures of the salt-bearing, massive reddish sandstones of Permo-Trias age, which have a strike of north 30° west and a steep dip towards the south-west. There is nevertheless considerable confusion in the dips along the road, and a good deal of folding appears to have taken place. I here saw the "Yen-ta-shu," a Chinese official of about 40 years of age, who received me in a friendly manner and accompanied me on a visit to the Tien-erh-ching well. I found him very anxious for advice as to how the outputs of brine might

be increased, and he further asked me where favourable places might be found in which to commence new drifts and wells. The well is a large one, situated in the middle of the village with its storage tanks close at hand; it is deep and is worked in the usual manner. The output of brine appeared to me to be greater than at some of the other places, but it does not contain so large a percentage of soluble sodium chloride, which accounts for the fact that there are over 70 batteries of pans used for boiling down brine in Tien-erh-ching. The monthly production of salt is said to be about 40,000 catties. The organization differs little from that of the Ta-ching well and the prices paid are the same, *viz.*, buying price from the maker, Tls. .9 per 100 catties. The licenses for all the wells in this valley are the same as the Shih-men-ching one, *i.e.*, Tls. 64 per mensem.

In every part of the province of Yünnan the supply of salt is hardly equal to the demand of the population for it. The area under description is no exception to this rule although the consumption per individual is probably reduced to a very low limit. The cost of native salt in districts far removed from the centres of production is so prohibitive that the article is a luxury to be purchased occasionally only by the poor, and forms to this day one of the principal media of exchange between the Chinese and the indigenous tribes who surround them. Illicit salt manufacture is an offence nominally punishable with the extreme penalty of the law, and it is only by dealing with the law-breakers in a severe manner that the Government monopoly can be strictly maintained. The quality of the salt supplied is of the very poorest grade, and cannot be in any way compared with the material to which Europeans are accustomed. Injurious salts and insoluble matters must be present in most specimens, for no attempts at refining are ever made. The excessive cost of salt in Yünnan is due partly to the heavy taxation which it has to bear in every stage of its manufacture and partly also to the great cost of transportation by mule caravan and porters over rough tracks in an exceedingly mountainous country. Railways running through Yünnan will certainly capture much of the salt traffic and do away with the latter evil to a great extent. A railway from Bhamo or Têng-yüeh to Ta-li Fu would cross the route of the salt caravan from Yün-lung Chou near Yung-ping Hsien, and would at once

Future developments
of the Yun-lung Chou
salt-field.

enter into successful competition with the overland road transport; instead of having to travel 75 miles by mule caravan across the Mekong watershed to Yung-chang Fu, or 122 miles across the high mountains and deep valleys of the Mekong, Salween and Shweli rivers to Têng-yüeh, a journey of some 40 miles would bring the salt into touch with the railway at Yung-ping Hsien. The railway therefore would gain the freight to be made by the distribution of native salt in the Western Circuit of Yunnan and would be the means of a considerable reduction in the price of salt throughout the Yung-ch'ang Fu, Têng-yüeh Ting and adjoining areas.

The Burma-China Convention of 1894-1897 prohibits the import of salt from Burma into Yunnan. Under these conditions it would be a waste of time to discuss the probable effect a railway would have on the trans-frontier carriage of salt. At the same time there are other features of the Yunnan salt supply which have some bearing on the importation of salt from Burma, which it is within the province of the economic geologist to point out. It is certain that the output of native salt in Yunnan is slowly declining, a state of affairs readily understood when it is remembered that there are no workings in the province which touch the deep-seated deposits, and that the shallow wells and drifts have been worked so actively and continuously by the Chinese, as to be now in a condition verging on exhaustion. Everywhere in the province the same story is told, a story of the former prosperity and present decline of the salt-producing centres.

The output from the Yunnan wells could be greatly increased by the introduction of simple machinery, especially for the operation of pumping and quick transmission of the brine. I also believe that modern drilling and pumping machinery with some improved method of evaporation could be profitably installed in other places at present unknown to the Chinese, where there is reason to suspect the existence of the salt-bearing horizons of the Upper Permian Red Beds, which are lying buried under considerable thicknesses of later Mesozoic strata.

Salt in the Wei-yuan T'ing district.

Wei-yüan T'ing is a small and poor city lying at an elevation of 3,150 feet in the valley of the Wei-yüan T'ing (Lat. 28° 30', Long. 106° 45'). Chiang. It is under the jurisdiction of the Pu-erh Fu prefect, but is a place of little

importance as it is not situated on or near any main trade route. It lies in a plain some 12 miles long and 3 miles broad, traversed by the river of the same name. It was formerly the capital of a Shan State named Mông Wa and the population is still largely Shan as it is a malarious neighbourhood inimical to the Chinese. The principal product of the region is salt.

The geology of this field is much the same as that of the others ; rocks of the Red Beds series build up the whole of the surrounding country and stretch for at least 30 miles to the north-west and south-west of Wei-yüan T'ing. Hsiang-yen-ching, the first stage, is 10 miles south-south-west of the city. The road traverses the level plain of the river for most of the way, then arises gently at its end and drops steeply into Hsiang-yen-ching,—elevation 3,500 feet. The only rock exposures seen were in the last mile and consisted of pinkish sandstones striking a few degrees west of north. In the stream-bed just beyond the river fine-grained, soft reddish sandstones with false bedding and well-marked jointing strike north and south. The rolled boulders and pebbles in the stream-bed give a very good indication of the various kinds of local rocks of the series. I found very fine-grained, dark red-sandstones, light red, soft sandstones, hard reddish-black sandstones with small inclusions of dark red clay, hard red marls, light red and yellow sandstones with gritty bands, rounded pieces of dull quartz and clouded yellowish felspar about the size of peas.

The village has two productive salt mines and two underground wells of the usual type with brine-raising bamboo pumps. Another well was in the process of being sunk and had reached a depth of 60 feet. The wells are all in the village. The mine lies in a narrow valley to the north-east about $\frac{3}{4}$ mile away. Its shaft is well timbered and slopes steeply from the surface. I wished to go underground but was told that the workings were very distant, low and tortuous, so I did not press the matter in face of this obvious opposition. The mine is said to be 30 years old. A large shed is erected over the mouth of the shaft for the storage of the excavated rock-salt. This was seen to be of a clean crystalline nature occurring abundantly in a red marl. In the shed there is an overseer's office where the output is checked

Route and geology of
the journey

Salt at Hsiang-yen-
ching

and tallied. The material is broken up in the shed and then taken in baskets to the town. Here it is placed in small wicker-work baskets suspended in large wooden tanks filled with water. The baskets are hung from cross pieces placed over the tank in such a way that they can be raised and lowered. One tank takes about 20 baskets. The salt dissolves and the mud settles down. From time to time the baskets are examined and the material broken up until a salt-free red silt is left. The brine is then raised by a pump and flows down a bamboo pipe into a stone-lined storage tank. Both tank and well are often in the furnace house. The boiling-down process is identical with the practice on other fields and need not be described again. If anything, conditions are dirtier and more insanitary here than elsewhere. The furnace houses are the homes of large families and the gutters carrying the brine run along the village streets alongside the sewers. A great deal of the boiling is done by Shans and a Shan official is in charge. About 200 coolies find employment in mining and brine-boiling here. Miners receive 7 candareens per 100 catties of crude salt mined and carriers 5 candareens for bringing out the same amount. There are 30 batteries of 6 to 10 pans each. The monthly production was given at 250,000 catties or 140 tons approximately. The official price paid for the salt was Tls. 1·8 per 100 catties. Its official selling price was Tls. 4·82. The tax per 100 catties was Tls. 3·18. Preventive work is performed by an armed guard of 30 men under the control of the local Shan chief.

Ho-ti-tang is a small village 12 miles to the south-south-west of Hsiang-yen-ching. The road ascends quickly out of the first valley and then descends into another at 6 miles. Both streams are tributaries of the Wei-yüan-chiang. The second stream is crossed and re-crossed many times. Numerous exposures of red shales and sandstones are seen, the former weathering down into irregular fragments. The country is dissected up by small tributary streams and there is much vegetation. At 8 miles thin oolitic limestone bands are interbedded in the red shales. The exposed parts of the bands simulate an organic structure but this is due to the weathering out of the oolites. I found no fossils. The road now leaves the valley and still keeping south-south-west rises to 5,400 feet at 9 miles, followed by a steep descent of 2 miles and then winds

along into Ho-to-tang, which has an elevation of 4,300 feet. In the stream-bed at the river hard, fine-grained red, and hard bluish-white sandstones with quartz infiltrations alternate with the usual type of irregularly fracturing, soft, red, marly shales. The whole series strikes north and south and dips at 45° — 50° to the west.

Ho-ti-tang, or as it is also known I-shang-ching, has two salt mines, which were opened about the year 1899. The processes of extraction and manufacture are identical with those in vogue at Hsiang-yen-ching and need not be repeated. The boiling-sheds are located in the village and the industry is in the hands of Chinese who appear to form a more prosperous community than the Shans of Hsiang-yen-ching. The boiler-houses are large, commodious brick structures with tiled roofs and are cleaner and better appointed generally than those at the other locality. 80 coolies find employment; miners are paid 1 mace per 100 catties of rock-salt; porters in the mines get 5 candareens. There are 8 batteries of 10 or 15 pans each. The official price paid for the salt is Tls. 1.80 per 100 catties; the official selling price is Tls. 4.82 per 100 catties; the salt tax amounts to Tls. 3.10 per 100 catties. The average monthly production is about 150,000 catties or 84 tons approximately.

There are several other salt-mines and brine-wells in this region but I did not succeed in obtaining a list of them. On the S.E. frontier sheet no. 12 N. W. (1"=4 miles), a salt-mine is shown 7 or 8 miles to the south-south-west of Wei-yüan T'ing at the edge of the valley. A number of mines are also indicated in the valley of an unnamed tributary of the Mekong, 20—25 miles south-west of Meng-ka, as the crow flies. Davies visited a brine-well at Hsi-kung-ching, 8 miles north of Wei-yüan T'ing along the Chen-yüan-t'ing road (D., p. 199). The production of the field is sent to Keng-ma, Mien-ning T'ing, the Shan States west and south-west of Yun Chou and to the Lo-herh mountains. It supplies therefore the wants of the Shan and wilder populations of these parts of Yünnan.

Salt of the P'u-erh Fu neighbourhood.

There are several salt-producing centres around P'u-erh Fu (lat. $23^{\circ} 5'$: long. $101^{\circ} 5'$) but I was only able to visit one at

Mo-hei. However, it is probably the largest and most important producer in this part of Yünnan.

The important city of P'u-erh Fu, lies at an elevation of 4,500 feet in a small plain of its own, surrounded by limestone hills. Mo-hei is 12 miles to the north-east of the city along the main route to the capital. Permo-Carboniferous limestones continue for a few miles and are then followed by typical rocks of the Red Beds series. The road gradually rises, attaining an elevation of 6,200 feet at 8 miles and then descends rapidly into the valley in the bottom of which Mo-hei is built at an elevation of 4,200 feet.

At one time a salt-mine was worked at old Mo-hei, but it became exhausted and the present output comes from a mine opened at new Mo-hei, one mile further up stream. There is also a brine-well near the same place. The processes of mining, leaching and boiling are the same as elsewhere. The evaporating sheds, of which there are 28, are large and clean. Each furnace carries 24 pans in 6 rows of 4 each. About 300 miners and coolies are employed and the monthly output is 600,000 catties or 334 tons approximately. The salt-boiler receives Tls. 1.1 per 100 catties. The Government selling price is Tls. 4.82 per 100 catties. The Government tax is Tls. 3.20 per 100 catties.

Salt near Lang-Ch'üung Hsien (lat. $26^{\circ} 6'$: long. $99^{\circ} 55'$).

Logan Jack has described the salt works of Chow Ho (Chiao-hou-ching) a small village about 10 miles west of Lang Chiung Hsien, in the following words:—For the first time in China we saw rock-salt, a little dark in colour but fairly pure, and entirely soluble, with the exception of a trifling residue of silica. The rock is sawn into blocks of varying sizes convenient for transport and sale. There are also brine wells, the brine being led down in long conduits from the hillside to evaporation works in the village. The firewood for the furnaces is floated down the river, and caught and stacked at the village above, Chow Ho. (Jack, *op. cit.*, p. 189).

The brine-wells of An-ning Chou (lat. $24^{\circ} 56'$: long. $102^{\circ} 44'$).

An-ning Chou is a small town one day's march to the west of the capital, along the main trade route to Ta-li Fu. Though now

in a broken and decayed state, evidences are not wanting that in former times the town was of some importance. The remains of a large wall and gates, the ruins of temples and bridges, and the long streets, now bordered by poor hovels, all go to prove this.

Around all the salt-mines and brine-wells of Yünnan, a large population generally exists, which is entirely dependent for a living on the salt industry. (This is especially noticeable since in most other parts the number of people in a particular area is, as a rule, limited entirely by the amount of land available for cultivation and by the supply of water for irrigation.) Should the mines or wells become exhausted, as they have done at An-ning Chou, then a migration of the population is bound to take place with more or less disastrous results to the locality.

Considered with respect to the output of salt for the whole province, the brine wells of An-ning Chou are of no particular importance and the following description is given to illustrate the persistence with which even small deposits are worked by the Chinese, and their ingenuity in overcoming natural difficulties. Duclos has already given a brief account of the wells. (Du., pp. 290-291).

Around An-ning Chou there is a considerable development of massive red sandstones and other rocks which are much the same as those found about the saliferous localities of the Ting-yüan Hsien district. Towards the east and south-east of An-ning Chou, Permo-Carboniferous limestones underlie these red beds.

The brine-wells and salt-works are within the city near the north wall and close by the *yamen* of the local magistrate.

Three wells were being worked in March 1908, at the time of my visit. Owing to their greater depth some modification of the ordinary windlass is necessary, and it was found that instead of the form described from the Ting-yüan Hsien neighbourhood, worked by four men, a double handle is attached to the axle and is operated by eight, usually four men and four women. Attached to the axle are the ordinary double untanned leather carriers, so arranged that while one is ascending with a load the other is descending to be filled.

The brine is very weak, and before being boiled down is concentrated by the following methods. It is led away in long open channels to shallow pools, which expose as much of the liquid

as possible and so favour evaporation. Beds of dried earth are systematically arranged near these pools and are periodically drenched by the salt liquors which are baled out and thrown over them. Aided by the sun and the wind the water evaporates, and the operation is repeated until the earth will take up no more salt. It is then leached out with water in other tanks, and the dirty salt liquors so obtained, after being filtered through beds of charcoal, ashes and sand, give a clear brine of much greater concentration than the original liquid from the wells. The treatment of the brine after this is precisely the same as that carried out at other places. The small amounts of salt so produced are taken by the officials of the Salt Monopoly and doubtless find their way into the open market by way of Yünnan Fu.

MISCELLANEOUS MINERALS.

Mercury.

Cinnabar probably occurs in Yünnan, several specimens were shown to me at various places though some of them may have come from the well-known mines in the neighbouring province of Kuei Chou. At Yun-lung Chou, I heard of a mercury mine 3 or 4 days' journey towards the north but I was unable to spare the time necessary to verify the information. According to Rocher, (R., p. 247), several cinnabar deposits were worked in the Ta-li prefecture before the rebellion. This would include the Yun-lung Chou locality, in all probability. Rocher describes the treatment of the ore, which consists of roasting in a furnace; the vapours are condensed in a kind of jar, three or four of which are placed on each side of the furnace and connected by tubes of glazed earthenware. Water is placed at the bottom of the jars to aid the condensation of the vapours. Near Ta-chuang there was a deposit containing native mercury; after removing the metal, the ores were subjected to a high temperature in a retort and the vapour condensed in receivers with water. This mine was abandoned during the rebellion and has not been re-opened. When Logan Jack was travelling from Hsiao-wei-shi to Wei-hsi-T'ing he was informed by a member of his escort that there was a quicksilver (cinnabar) mine beyond the right walls of the valley below Ta-pien-ta. "He so minutely described the process

of distillation, that I think there can be no mistake about it, although we saw no specimens" (Logan Jack, *op. cit.*, p. 178).

Antimony.

I was shown specimens of stibnite frequently in Eastern Yünnan, but never met with the mineral in the western parts of the province. The Director of the Bureau of Mines in Yünnan Fu had a fine series of specimens of the ore, both native and refined. I was told that these came from the Kai Fu prefecture.

It is a well-known fact that antimony ores occur in this vicinity and also about Kwang-nan Fu on the borders of Kwang-si. Rights were granted by the Government to mine and smelt them in 1909. In 1913, according to the Mêng-tzü Customs reports, 427 tons of antimony were exported through that port, and in 1914, 335 tons.

Cobalt.

Leclère states that a cobalt-bearing oxide of manganese is mined in the north of the Tung-chuan prefecture. It has supplied the dyes used in the manufacture of the famous Kuang-si blue porcelain for long periods. (Le., p. 446).

Marble.

Ta-li Fu marble is famous throughout China and is used for making ornamental plaques, tombstones, etc. I have visited the quarries which are located on the high mountain wall a few miles to the north-north-west of the city. A crystalline marble crops out in them. It is a fine-grained variety with patches and irregular spots of dark micas and amphiboles in a white background, which produce fantastic effects much appreciated by the cultured Chinese. Large quantities of the stone are still available, but the industry is controlled by the dealers, rather than by the quarry-owners or the polishers. The stone is all prepared locally and is often stained and then covered with a coating of white wax to emphasize the colour designs.

Semi-precious stones.

The jadeite which is worked up in Têng-yüeh comes from the mines of the Mogaung subdivision of the Myitkyina district in

Burma. The best qualities are said to be exported direct, in the rough, to Canton, and only the second-grade stone is sent to Yünnan. Nevertheless, jade-cutting and -polishing is a staple trade in Têng-yüeh and I have already commented on the subject in the section of this report dealing with trade.

Amber ornaments are common. Most of the specimens I examined bore the characteristic fluorescence of the Burmese material.

Turquoise ornaments are always worn by the Yunnanese Tibetans, but the stone is not of local origin.

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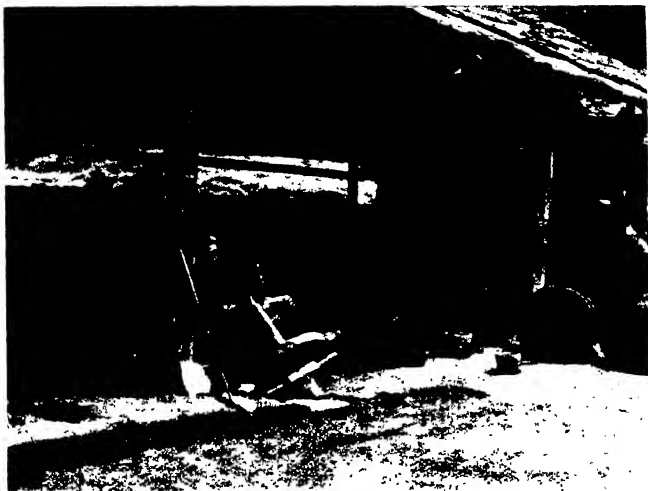
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MOULD SHED OF AN IRON FOUNDRY (note piston of cylindrical blower).



Photographs by J. Coggin Brown.

G. S. I. Calcutta.

FOUNDRY FOR IRON PANS, NEAR SHUN-NING FU.



FIG 1. LOW IRON FURNACE OF THE TIEN-TAUNG KUAN IN BLAST.





FIG 1 SMALL IRON BLAST FURNACE IN THE TIEN-TAUNG KUAN, FRONT VIEW

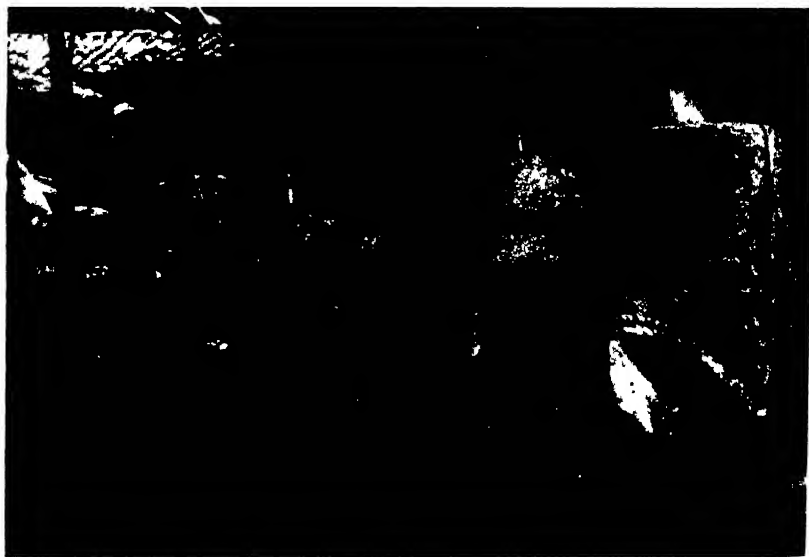




FIG. 1. KILNS FOR CALCINING COPPER ORES, PO-P'ING-CH'ANG



Photographs by J. Coggin Brown.

FIG. 2. HIGH BLAST FURNACES FOR SMELTING COPPER ORES, PO-P'ING-CH'ANG.

Front view of a bench of four.



Photographed by J. C. G. in Brou

ARRANGEMENT FOR CRUSHING GALENA, MING-KUAN



FIG 1 BACK VIEW OF LEAD BLAST FURNACES IN THE MING-KUAN, (Showing blower)



Photographs by J. Coggin Brown

G. S. I. Calcutta

FIG 2 FRONT VIEW OF LEAD BLAST FURNACES IN THE MING-KUAN

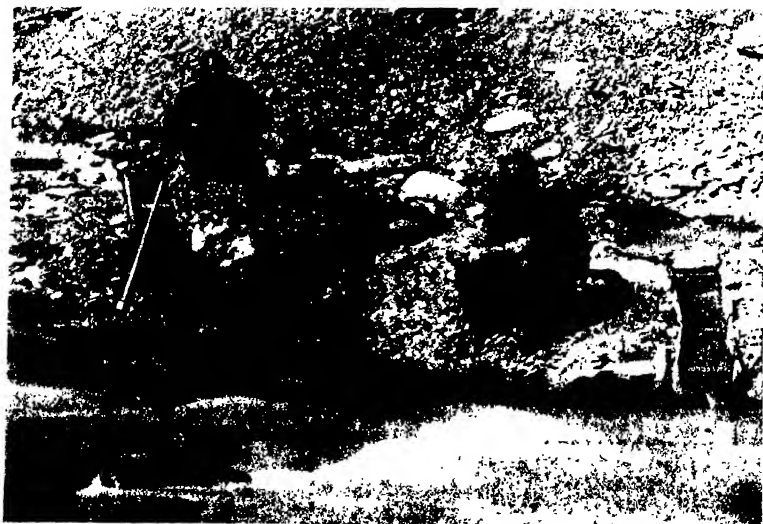


Photo, attached for Cassin's box

WORKINGS IN A HIGH LEVEL GOLD-BEARING BENCH DEPOSIT, NEAR A-LU-SHIH
to N. Calcutta



FIG. 1. GOLD WASHING IN THE YANG-TZE NEAR CHIN-CH'ANG-KAI.



Photographs by J. Coggin Brown.

G. S. I. Calcutta.

FIG. 2. GOLD WASHING NEAR A-LU-SHIH.

MEMOIRS
OF
THE GEOLOGICAL SURVEY OF INDIA

VOLUME XLVII, PART 2.

THE ALKALINE LAKES AND THE SODA INDUSTRY OF SIND. BY
G. DE P. COTTER, B.A., SC.D. (DUB.), F.G.S., *Superintendent,
Geological Survey of India.*

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Superintendent, Geological Survey of India.

CHAPTER I.

INTRODUCTORY.

THE soda industry of Sind appears to have existed from time immemorial, although it has attracted little notice, on account of the smallness of the output. No scientific examination has hitherto been made of these deposits, but certain samples of alkali were analysed in 1901 in the laboratory of the Reporter on Economic Products to the Government of India (Mr. I. H. Burkill). In the maps of the Survey of India, published from 1860 to 1863 (scale 1"=1 mile), one of the lakes of the desert is marked "*Natron* producing."¹ The soda is also described as *Natron* in the first edition of the Sind Gazetteer published 1874.² "In the desert portion of Khairpur" says the Gazetteer "are pits of natron—an impure sesquicarbonate of soda and always found containing sulphate of soda and chloride of sodium. It is generally obtained by means of evaporation. These natron pits are a source of income to the ruling Mir, as many as a thousand camel-loads of this substance being annually exported to Northern

¹ Sheet 43, Sind Survey, scale 1"=1 mile.

² Sind Gazetteer, 1874, p. 407.

and Central India, as also to the sea-board, each camel-load being taxed at 2½ rupees." A further mention of soda in this Gazetteer is as follows. "Thar and Parkar.....Soda, or *khara chania*, is obtained from the *dhandhs*, and exported, and *cheroli*, a sulphate of lime, or gypsum, is found near the village of Ghulam Nabi jo Got."¹

The analyses made by Mr. Burkill, prove that the mineral is trona (urao), and not natron as it is called above. The term natron is, however, loosely used in the Gazetteer, while the description of the compound as a sesquicarbonate of soda shows that the mineral now known as trona was alluded to, since the mineralogists of that time regarded trona as a sesquicarbonate.

The late war with Germany and consequent difficulty of obtaining supplies from England drew the attention of the Government of India and the Indian Munitions Board to the examination of those natural resources of India which in time of peace have remained undeveloped owing to the low prices of imported commodities. Since manufactured soda in England averaged in price between £4 and £5 per ton before the outbreak of war, the development of natural deposits of trona could only be regarded as a paying proposition in cases where the deposits occurred on a vast scale, as at Owens Lake in California or Lake Magadi in the British East Africa protectorate. In view of the low price, the development of small deposits such as those of the Sind desert, situated as they are at a considerable distance from the railway, was not regarded as commercially feasible except for local trade. In 1917 the question of the examination of the soda of Sind was taken up by the Indian Munitions Board and by the Geological Survey of India, and it was finally decided that an officer should be sent to Sind to examine these deposits.

Accordingly I received orders to tour in Sind in the cold weather of 1918-19, and to report upon the soda deposits there.

My tour lasted from November 9th to February the 13th, although the actual work of investigation was done in December and January. When I reached Sukkur early in November, I was fortunate enough to find the Commissioner in Sind (Mr. H. S. Lawrence, C.S.I., I.C.S.) in Sukkur on tour. Mr. Lawrence was greatly interested in my investigation, and very greatly assisted

¹, Sind Gazetteer, 1874, p. 825.

me by deputing the Assistant Commissioner of Salt, Excise, and Opium, Mr. E. L. Thurley to accompany me on my tour. Mr. Thurley joined me just before Christmas, and gave me the full assistance of his department in collecting samples of lake-water and dry specimens of salt and alkali. I was thus enabled to handle a far greater number of specimens than I could have done unassisted. In Khairpur State, the Vazir of Khairpur sent one of the State officials connected with the soda trade, Mr. Mohammed Khan, to my camp. This officer gave me great help in showing me the various *dhands*, and accompanying me on tour throughout the State. Without his aid, travelling in this desert country would have been exceedingly difficult.

In the taluqas of Nawabshah, Sanghar, and Khipro, I received much help from the Mukhtiarkars, who both assisted in the collection of samples, and in obtaining information from the local villagers regarding *dhands* which had ceased to yield *chaniho*. My thanks are due to these officials, through whose aid I was enabled to make a fairly comprehensive survey of the soda industry of Sind.

In order to examine the water of the alkaline lakes, I came equipped with a small travelling laboratory
 Method of exami-
 nation. for volumetric analysis. It was my practice to visit each *dhand*, and after making the usual observations regarding size, depth, etc., fill a bottle with the bittern, which was afterwards tested in camp. On arrival in camp the specific gravity was first taken by means of hydrometers graduated to three places of decimals; the bittern was then tested for total alkalinity with half-normal acid, and usually for salinity with standard silver nitrate of the same strength. Roughly graduated school burettes were used, so that the results are not so accurate as those made in a laboratory, although they are sufficiently accurate for all practical purposes.

It was not found possible to determine the sulphate content volumetrically. An attempt was made to do so by Wildenstein's method. The bitterns are however so much coloured by organic matter, that the end-point of the reaction was quite impossible to determine.

Fifty-seven samples of bitterns were collected and sent to the Geological Survey Laboratory in Calcutta for further more accurate analysis. Besides these a large number of specimens of crude trona (*chaniho*) were collected and sent to Calcutta for analysis,

This report deals mainly with an area in Eastern Sind, comprised by the southern half of the Khairpur State, the eastern half of Nawabshah district, and the northern half of Thar and Parkar (see Plate 14).

This area is entirely covered by alluvial clays or by wind-blown sand, and there are no outcrops of rock visible.

It is bisected in a north-south direction by the East Nara Canal. This canal lies in the bed of an ancient river, known to history as the Hakro or Lost River of Sind.¹ The only other canal which need be mentioned is the Jamrao, which leaves the East Nara, near the southern boundary of Khairpur State, and runs in a S.W. direction into Nawabshah district, finally turning south into Thar and Parkar.

Roughly speaking the area covered by alluvial clays and silts lies entirely west of the Nara, and south of the Jamrao. The area covered by wind-blown sand includes all the country east of the Nara, and north of the Jamrao Canal. I shall proceed to give short descriptions of each of these areas.

The alluvial country south of the Jamrao and east of the Nara, is covered by fine clays and silts, which, it is important to observe, are very highly impervious to water. This fact has been demonstrated by observations of leakage of water from the Jamrao and from other canals, which show that while that part of the canal which runs through sand-hills allows large amounts of water to escape through the walls, only a very small percentage of water leaks from the canal where it runs through alluvium.

A large portion of the soil of this country is unfit for cultivation, being highly charged with mineral salts, known as *reh* or *kalar*. These are mixtures of the chloride, sulphate, and carbonate of sodium, but of very variable composition, the chloride being largely predominant in this area.

A few halophytes grow upon this soil, the most abundant being small shrubs of the Goosefoot order (*Salsola*, *Sueda*).

Regarding these plants Brandis² remarks, "As far as known, their roots largely take up salts of sodium, while most other trees and shrubs mainly take up potassium salts, though sodium salts

¹ Sind Gazetteer, 1907, p. 323, also *J. As. Soc. Bengal*, LXI, pt. 1.

² Sir D. Brandis, "Indian Trees", p. 518.

are always present in the soil. Their ashes are rich in sodium chloride, and many species were formerly and are still here and there employed to make an impure carbonate of soda (*Barilla*, *Sajji*)."

In Sind and in the Kachhi district of Kalat, which is geographically a continuation of the Sind plain, small quantities of this crude carbonate (*barilla* or *sajji*) are manufactured by burning and lixiviating the ashes of these chenopodiaceous plants, locally known as *lani*. Doubtless a certain amount of reduction takes place during the process of burning, in a manner crudely similar to that of the Leblanc process. I mean that the roots of these plants which contain various sodium salts, carbon in the woody tissue, and a certain amount of calcium carbonate in the calcareous soil mixed with the roots, react under the influence of heat, so that the total amount of carbonate after burning is considerably greater than that originally present.

The soda produced in this manner is small in quantity, and lies outside the scope of my enquiry. I need not therefore allude to it again.

Another tree of common occurrence, especially near the saline *dhands*, is the tamarisk. I shall allude subsequently to the curious apparent connection between the rounded mounds of *chirol* (gypsum) seen so frequently on the shores of saline *dhands*, and this tree.

Several other halophytes are found, but they do not appear to be of interest in my present enquiry.

The alluvial country is fairly free from large sand-dunes, but small incipient crescent-shape dunes, technically known to science as *barkhans*, are of common occurrence throughout this area. Near Karachi they have received a special description from Mr. R. D. Oldham.¹

The second tract, comprising the country east of the Nara and north of the Jamrao, is entirely covered with wind-blown sand. East of the Nara and in the south of Thar and Parkar, the sand-hills are aligned in long parallel ridges, called in Sindhi *bhats*, the direction being parallel to that of the prevailing monsoon winds. In the south of Thar and Parkar near Diplo, Mithi, Nagar, and

¹ R. D. Oldham, *Mem. Geol. Sur. Ind.*, Vol. XXXIV, pt. 3.

Umarkot, the general direction is N.E.-S.W., or E.N.E.-W.S.W. Near Khipro the direction changes to N.E. by N. and finally N.N.E. in Sanghar taluqa and the south of Khairpur State. In that part of Khairpur State which lies west of the Nara, the direction of the *bhils* is almost due north. Mr. R. D. Oldham, in the 2nd edition of the *Manual of the Geology of India*,¹ has explained and illustrated the formation of the sand-hills of the Sind desert. He recognises two types of sand-hills, (1) the longitudinal ridges or *bhils*, aligned as has been noted above, parallel to the direction of the monsoon winds, and (2) the transverse dunes, aligned more irregularly, but generally transversely to the prevailing direction of the wind. Oldham remarks that "the restriction of the longitudinal type of sand-hill to the seaward and western margins of the desert appears to show that they are connected with a greater wind force than the transverse type."

In the area with which I am dealing, the most southerly portion of the sand-covered country in the Khipro taluqa, is characterised by long parallel sand-hills. Between the sand-hills, the old original alluvial soil, which must everywhere underlie the sand-hills, is either at or very close to the surface. The valleys between the *bhils* or sand-ranges are locally known as *talis*, or *tullees* as spelt on the maps.

The winds which blow from the Rann of Kachh are strongest near the coast, and in this coastal area characterised by strong winds, the *bhils* are in unconnected parallel ridges. The further north we travel, the more do we observe the *bhils* to be connected by transverse ridges. In the southern part of the Khairpur State west of the Nara, the *bhils* or sand-hills have in places almost a haphazard appearance, although the north-south trend of the larger *bhils* cannot fail to be noticed if looked for. This is a region of small oval shaped *talis* (valleys or hollows between the sand-hills) some of which contain shallow lakes (*dhands*) and some of which are dry but studded with green shrubs and trees. The same features are found on the east of the Nara in Khairpur State for a distance of about 25 miles from this canal.

The eastern part of the Khairpur State lies in a rather different type of country. To the east of the old fort of Kot Jubo the

¹ *Manual of the Geol. of Ind.*, 2nd edition, p. 455.

See also Holland and Christie, *Rec. Geol. Sur. Ind.*, Vol. XXXVIII, p. 163.

quantity of sand deposited by the wind has been so great as to cover completely the whole face of the country with plateaux of deep sand. These plateaux of soft deep sand, continually changing their shape with every breeze, over which all tracks are obliterated in a few hours, are called by the Sindhis *dra-in*. The *dra-ins* are difficult to cross, since one's feet sink deep into the sand. Only the local camels can negotiate them. When crossing the *dra-ins*, one finds oneself in a veritable billowy sea of sand with no single scrap of vegetation to vary the monotony of the brown hills. The sand is disposed in beautiful irregular curves of hills and hollows; it is impossible to cross in a straight line, the path being a series of semicircles, whereby the distance is greatly lengthened in travelling from one point to another. Yet after travelling thus over this barren waste for hours, one may suddenly come upon a hollow rather deeper than usual, filled with vegetation and greenery. Such hollows are locally known as *kochur*, and there is usually damp ground or perhaps a little water at their bottoms. Other still deeper hollows contain shallow lakes or *dhands* (also called in this neighbourhood *tikh* or *daba*).

Although it is customary to speak of this part of Sind as a desert, it is by no means so devoid of vegetation as Baluchistan. Only the *dra-ins* are entirely barren; the *bhils* and *talis* which cover most of the country have quite a vigorous flora of their own. The average rainfall at Umarkot for the three years ending 1903 was 6 inches, at Hyderabad the average rainfall was 7 inches; these figures being greater than those for western Sind and the Kachhi district of Kalat, and nearly equal to the figures for the highlands of Baluchistan. The Sind desert therefore receives quite an appreciable amount of rain. Doubtless a large proportion of this is lost again by evaporation, but still a certain percentage is absorbed by the sand, through which it sinks downwards until it is held up by the impervious alluvial clay which underlies the desert sand. As a result the basal layers of desert sand are kept moist by the absorbed rain-water, and yield springs in places where a deep *tali* exposes the lower layers of the sand. There is a special term in Sindhi for this kind of percolating water, it is called *sim* water, and many *dhands* are also termed *sims*, which signifies that the water of these particular *dhands* is not regarded as surface rain-water nor as flood water from the Nara, but as percolating water from the lower layer of desert sand. On the other hand the plains of western

Sind and of Kachhi, which are free from sand, do not absorb so large a percentage of water; the rain-storms give rise to sudden floods, but the water is rapidly carried away into the *nullahs*, and finally reaches the Indus.

Like all desert plains that of Sind is characterised by the absence of water-courses; such as do exist are water-courses in decay like the old river bed of the East Nara or the Sang nullah on the site of which the Jamrao Canal is constructed. I have not made any systematic examination of the desert trees, but in passing, it may be as well to mention a few of the more common types. Perhaps the commonest tree is *Kundi* (*Prosopis spicigera*) a thorny middle size tree of the Mimosa family; *Phog* (*Calligonum polygonoides*) an almost leafless shrub; *Kirar* (*Capparis aphylla*) a leafless caper, as its name implies; *Khip* (*Leptadenia spartium*) a twiggy shrub from the fibre of which ropes are made; *Kabbar* (*Salvadora persica*) an evergreen shrub, very common in the bottoms of salt *talis*. The tamarisk is common in the south in the Khipro taluqa, but rare in the sand-hills of Khairpur. A cactus-like *Euphorbia* (*E. nereifolia*) has a similar distribution, being common in Khipro and rare in Khairpur.

The desert is then by no means the barren waste that one might have imagined. Grasses are common in the bottoms of *talis*, the country supports a few cattle, sheep, goats, and donkeys, while there is abundant fodder for camels. The inhabitants are all herdsmen, and live mainly on milk, curds, meat, etc. There are numerous wells, although the water is frequently brackish.

It has been stated that the water which percolates through the basal layers of the desert sand where it rests upon the impervious alluvial clays of the Sind plains, emerges in any low-lying places to form marshes or lakes (*dhands*). Since the soil of the Sind plain is heavily charged with sodium salts, this percolating water carries these salts away in solution from the buried soil underlying the sand hills, and brings them into the *dhands*. The whole process is very similar to the transport of soluble salts by rivers to the sea, and results in a constantly increasing accumulation of salts in the *dhands*. While the water of a *dhand* may be strongly alkaline or saline, it is customary to find the *sim* or percolating water round the shores of the *dhand* sweet and drinkable, containing only a very small percentage of soluble salts. The water of Usar *dhand* in Khairpur, where I

encamped, has an alkalinity of 19.3 grams of Na_2CO_3 per litre, and is undrinkable. I had some holes dug on the shore, in which I found that the water was quite sweet and at a slightly higher level than that of the *dhand*.

From what has been said, it will now be apparent that the *dhands* of the Sind desert are really low-lying flat places where the original alluvial clay has remained uncovered by sand or has only a thin covering, and where the sand-hills are not entirely arranged in parallel *bhits*, but in a sort of network of parallel *bhits* connected by transverse ridges of sand. In this sort of country the *talis* or valleys between the *bhits* form oval enclosures where the water accumulates provided there is sufficient spring or *sim* water round the base of the *tali*. The *dhands* therefore, although often large expanses of water, are never very deep; a *dhand* of one mile in length may be only ten feet deep in the middle; they are in fact huge flat-bottomed evaporating pans, in which by continual evaporation the salts of the *sim* or spring water round their shores are continually being concentrated. As a general rule the shallower and smaller the *dhand*, the greater is the concentration of the solution. The shape is most frequently an oval or elongate ellipse, the long axis of which is parallel with the main *bhits*, that is parallel with the direction of the monsoon winds.

In the part of Sind with which I am dealing, the *dhands* fall into two groups. The first group are those on either side of the Nara at distances of from a quarter up to about seven miles. The second group are those east of Kot Jubo in the east of the Khairpur State.

The survey of 1860—65 shows the original state of the Nara group of *dhands*. In the old maps of this period one cannot fail to notice the numerous large *dhands* east of the Nara in the Khipro and Sanghar taluqas of Thar and Parkar, all of which are now either very much diminished in size or entirely dry *talis*. It is necessary to note the causes of the gradual desiccation of this area, which has resulted in a shrinkage of the former *chaniho*¹ producing area to narrower limits. According to the Sind Gazetteer,² the Nara, before its canalisation was "a channel or narrow valley in the sand-hills, through which the spill water from the left bank of the

¹ *Chaniho* is the term used in Sind to denote trona or natural soda.

² *Op. cit.* (1907 edition), p. 323.

Indus above Rohri found its way to the desert.....Upon Sir Bartle Frere's advice a survey of the valley was undertaken in 1852 and it was discovered that more spill water escaped from the Indus to the Eastern Nara than had previously been believed, but that, owing to the sandy nature of the valley and especially to numerous immense hollows in the desert, the water, except when a very large flood occurred, was entirely absorbed. Dams were immediately constructed which diverted the stream from the sandy hollows in which it was absorbed to the alluvial plain extending south of Mithrao."

In May 1859, a cutting was made at Rohri from the Indus to the Nara. In 1885 a head regulator was constructed at Rohri. Improvements continued to be made every year, and finally in 1899 the Jamrao Canal was completed and opened. This takes a large portion of the water of the Nara, and distributes it to the west of Thar and Parkar and part of Hyderabad.

To prevent flooding of the desert, the Nara has, in the Sanghar and Khipro taluqas, continuous banks on either side. The diversion of so much water to the alluvial plains to the west, has led to the gradual drying up of all the *dhands* on the east of the Nara in Khipro and Sanghar. Although many *dhands* still remain, the majority have vastly diminished in size or have become entirely dried up. A few *dhands* still exist whose waters are replenished by floods from the Nara, but the great majority of the present *dhands* derive their supplies of water from springs or *sims*, as has been explained above.

Near the head of the Jamrao Canal, embankments have been made for the purpose of controlling the flood water. As a result, the *dhands* of the Nawabshah taluqa have in many cases dried up.

North of the junction of the Jamrao and the Nara, that is, in Khairpur State, the *dhands* show the same general tendency towards desiccation, but in a much less marked degree, and their present condition is not vastly different from that of 1860.

As a rule the water of the *dhands* situated at a distance from the Nara is highly charged with salts, while that of *dhands* close to the Nara is in many cases fresh. This is due to the fact that owing to constant flooding in the past, the *dhands* close to the Nara have had their dissolved salts washed out of them by floods, and have never become concentrated. These fresh-water *dhands* are

easily recognised, both by the abundance of reeds and by the presence of crocodile, which can be seen in swarms.

In this Nara belt the brackish *dhands* of Khairpur are alkaline; those of Khipro are saline, while those of the Sanghar taluqa are of an intermediate type. The alkaline *dhands* can be distinguished even at a distance from the saline. Round the shores of the alkaline *dhands* and some little way into the *dhand*, there is abundant soft green grass, and abundant trees. The saline *dhands* are barren of grass, and except for a few halophytes such as tamarisk and saltworts, are very bare of trees. Small tamarisk bushes are however very common round the saline *dhands*, and their presence accounts for the very curious shapes of the hillocks of gypsum (*chiroli*) seen all round the shores of these *dhands*. It is well known that the tamarisk grows in places which are liable to be submerged in time of flood. Those which now grow on the shore of the *dhands*, were in former days liable to be completely submerged by floods, or may have been continually partially under water. The saline *dhands* have deposited great quantities of gypsum as well as salt, and it is clear that amongst other constituents of the salts washed into these *dhands* sulphate of calcium was abundant. The gypsum crystallises around the stems of the tamarisk. I have collected specimens of gypsum growing round branches of dead tamarisk from some of these *dhands*. The crystals are disposed radially around the branches of the tamarisk, so that the stems become thickened with a casing of white crystals of gypsum. The tree now looks like a tree covered with hoar-frost and frozen hard. The process of deposition of gypsum goes on, until the resemblance to a tree is lost, instead of a tree there is a small round hillock with innumerable rounded knobs. The cylinders of gypsum which surrounded the branches have broadened and coalesced until this curious shape is arrived at. If one of the knobs is broken off the remains of the decayed tamarisk stem will be found in the middle, and the crystals will be observed to radiate out from this central stem. Both stages of development are shown in Plate 13.

These mounds of *chiroli* (gypsum) are characteristic only of saline *dhands*. It is easy to see that in the presence of sodium carbonate, any calcium sulphate present would be precipitated as carbonate; hence no gypsum is found near the alkaline *dhands*.

It has been said that the alkaline *dhands* support a more luxuriant vegetation than the saline; they have other distinct characteristics.

Those which are more concentrated have a peculiar smell resembling that of decaying fish, while the water is of a red colour.

T. M. Chatard¹ ascribes the red colour of alkaline lakes to the presence of a crustacean (*Artemia salina*), which however is not known to occur in India. The red colour of the saline Sambar Lake in Rajputana is due, according to the researches of the Salt Department to algae.

The Sind *dhands* are subject to considerable seasonal variation in depth, being at their fullest after the monsoon rains, and lowest in May or June, just before the break of the rains. The very small or very shallow *dhands* dry up completely; the large *dhands* shrink considerably but do not as a rule dry up or become sufficiently concentrated to deposit their dissolved salts; it is only those *dhands* which are of a medium size, and shallow depth which deposit their soda without drying up completely; from these the best quality of soda is obtained, while those *dhands* which dry up completely yield much more impure deposits.

Turning now to the *dhands* near Kot Jubo, the majority of which are alkaline, a few saline, and a few fresh, it may be worthwhile to explain their connection with the *dra-ins*, and the source of their water.

An examination of Plate 16 will show that the country east of Kot Jubo is for the greater part covered by two large sand-plateaux or *dra-ins*, that to the west being known as the Kharori or Pur Chandar jo *dra-in*, and that to the east as the Sanoi je *dra-in*. Between these two *dra-ins* is a belt about two miles in breadth of *bhit* and *tali* running in a N.N.E. direction, and extending for over 12 miles in length. South of Kot Jubo and Pakhyaro *dhand*, the *dra-in* gives place to *bhit* and *tali* type of country. North of Kinri and Sahai *dhands* again the *dra-ins* diminish in breadth while the *bhit* and *tali* type of country becomes more common.

It is very evident that these two large sand-plateaux or *dra-ins* form reservoirs of a kind for the absorption of the monsoon rains. The presence of fresh-water at the bottoms of the numerous *kochurs*, and the presence in the very middle of the Pur Chandar jo *dra-in* of *sims* of fresh water shows that water is abundant in the lower levels of the sand of the *dra-in*. As a result, the Pur

¹ "Natural Soda; its Occurrence and Utilization" *Bull. U. S. Geol. Surv.*, No. 60, 1890, p. 95.

Chandar and Sano-i *dra-ins* are fringed with *dhands*, caused by percolating water escaping from the lower strata of the *dra-ins*, and accumulating in any low-lying places, where the bottoms of the *talhs* are at a sufficiently low level. Especially the belt of *bhut* and *talh* country between the two great *dra-ins* of Sano-i and Pur Chandar is studded with *dhands* which derive their supplies of *sim* water from both *dra-ins* on either flank. The fresh-water *sims* and *dhands* are supplied by water which percolates the sand, which is fairly free from salts, but this water is not at a sufficiently low level to tap the *reh* or *kalar* salts of the alluvial soil concealed beneath the desert sand. Probably all the fresh-water *sims* are at a higher level than the brackish.

None of the *dhands* are very deep, although another impression is given by a curious note on the Survey of India map about the Pur Chandar *jo dhand*. The note states that "This lake is of immense depth; supposed by the natives to be fathomless and the origin of Noah's deluge."¹ Mr. Mohammed Khan contrived a raft upon which I sent out a native with a long pole. He touched ground near the middle of the lake with the pole at a depth of about 15 feet and, I fear, damaged this picturesque legend.

¹ See sheet 44, scale 1 inch = 1 mile, Sind Survey.

CHAPTER II.

THE KHAIRPUR STATE ; NARA REGION.

It has been said that the *dhands* from which trona (*chaniho*) is produced fall into two groups, (1) the Nara group lying in a belt of country about 10 to 12 miles wide and bisected by the Nara, and (2) the group east of Kot Jubo in the east of the Khairpur State, near the border of Jaisalmer. The first group extends from the south of the Khairpur State into the Nawabshah and Thar and Parkar districts, while the second lies entirely in Khairpur. It will be convenient to subdivide the first group territorially into A. The Khairpur State *dhands*, Nara region; B. The *dhands* of the Nawabshah taluqa; C. The *dhands* of the Sanghar and Khipro taluqas of the Thar and Parkar district. In order to complete the description of the Khairpur State deposits, before describing those of British territory, I shall describe in Chapter III the second group of *dhands* east of Kot Jubo, and postpone the description of those subdivisions of group (1) which lie in British territory to the subsequent chapters.

The *dhands* with which the present chapter deals,—those of the Nara region, Khairpur State,—may again be divided into two sections, *viz.*, those west and those east of the East Nara.

In a letter dated November 2nd 1918 to the Political Agent, Khairpur State, the Vazir of Khairpur State gives a list of *dhands* yielding *khari chaniho*. Of the 68 *dhands* mentioned in this list, the following are west of the East Nara :—

Producing *dhands*
west of the Nara.

- | | |
|-----------------------|------------------------|
| 1. White Bitiro. | 10. Western Dabanwali. |
| 2. Lahuri. | 11. Parowali. |
| 3. Dail. | 12. Whichonaro. |
| 4. Guloo Wali. | 13. Chugari Chahewali. |
| 5. Dherioon. | 14. Nanganwala. |
| 6. Sukchahow. | 15. Tikini. |
| 7. Taraie Pir Nango. | 16. Bagarwala. |
| 8. Pharanwala. | 17. Kalarwali. |
| 9. Chugari Kalarwari. | 18. Bolahwali. |

19. Chilh.	22. Mitheri.
20. Kharri Chach Wari.	23. Dosewali.
21. Boogi.	

The order in which these names are given appears to be purely haphazard, and bears no relation to the geography of the district. Moreover in the Vazir's list, they are intermingled with the names of the *dhands* east of the Nara. The names are reproduced with the spelling and in the order in which they appear in the list.

It will be more suitable in the present report to consider the *dhands* in their proper geographical order, beginning with those to the north, and so working southwards towards the boundary of Nawabshah. The position of each *dhand* is shown in Plate 15.

- (1) **Dabranwari** (Western Dabanwali of Vazir's list) is shown on the map as Dubrunwaree Tullee. It was completely dried up, and had yielded no *chaniho* at the time of my visit. It was also dry in season 1912-13, and in season 1915-16, but produced well in other years since 1912.
- (2) **Bulah-wari** (Bolahwali of Vazir's list), marked Boolahwaree Tullee on map, is about 1 mile east of Dabranwari. It is an oval-shaped *dhand* about 300 yards long, and was 1 foot deep at the time of my visit. There were several piles of *chaniho* round its shore at the time of my visit. The *chaniho* was regarded by Mr. Mohammed Khan as 2nd grade in quality. In 1917-18, it is said to have yielded nearly 2,800 maunds of trona.
- (3) **Bagarwaro** or Bagarwala, 1 mile S.S.W. of Bulahwari and $\frac{1}{2}$ mile west of Bhitrajo Tul as marked on map. There are two *dhands* here which are really a westward extension of Bhitrawaro *dhand* or Bhitra jo Tul as it is named on the map. The name Bagar-war-o is equivalent to Baghal-wala or "Side-dhand" implying that it lies at the side of another, viz., the Bhitrawaro *dhand*. Bhitrawaro itself is a large brackish *dhand*, but is not sufficiently concentrated to deposit trona. Of the two *dhands* on its west margin, the first is small, about 80 by 40 yards, and yields very little *chaniho*. It was dry at the time of my visit. The further *dhand* is about 300 by 80 yards and was very nearly dried up. These two

dhands are said to have yielded nearly 2,800 maunds of *chaniho* in 1917-18. The analysis of a specimen of *chaniho* from the large *dhand* is given in Chapter VI.

- (4) **Dail**.—This *dhand* is 2 miles west of Bagarwaro, and was dried up at the time of my visit. Owing to its having remained dry, it had yielded no *chaniho*. In 1917-18 it was said to have yielded about 2,900 maunds.
- (5) **Sukchaho**, $1\frac{1}{2}$ miles S.S.W. of Bagarwaro and $\frac{1}{2}$ mile west of the large brackish *dhand* Bitriwari, is one of the largest producing *dhands* of this section west of the Nara. It is about 400 yards in length by 100 in breadth, the depth being about 1 foot at the time of my visit. It yields 2nd grade *chaniho*. In 1917-18 the amount produced was 2,700 maunds. The bittern had a specific gravity of 1.164 and contained 111.5 grams of Na_2CO_3 per litre. (In this and similar field analyses, the total alkalinity is estimated as sodium carbonate.) Analyses of its *chaniho*, and of its water are given in Chapter VI.
- (6) **Chughari Chahewari**, about 1 mile E.S.E. of Sukchaho, and lying between the two large brackish *dhands* of Bitriwari and Dangi Chhuowari, is a very small *dhand*, about 80 by 40 yards, which had a very little water at the time of my visit. The water contained 133 grams of Na_2CO_3 per litre. An analysis of this bittern will be found in Chapter VI.
- (7) **Chughari Kalarwari**, $1\frac{1}{2}$ miles S. by W. of the last-named *dhand* and about $\frac{1}{2}$ mile north of the large *dhand* Pir Naga or Pir Nanga, is also a small *dhand* similar to the last named, but was completely dry at the time of my visit; hence neither water nor trona could be collected.
- (8) **Tarai Pir Nanga** is a small *dhand* or rather a southward extension of the large Pir Nanga *dhand*, and lies to the immediate south of Pir Nanga. It was dry and had yielded no trona at the time of my visit. The Pir Nanga *dhand* itself is practically fresh-water with a specific gravity of 1.002, and an alkalinity equivalent to only 1.2 grams of Na_2CO_3 .
- (9) **Khariri** (or **Kharri**) **Chachwari**, called Chachwari to distinguish it from another Khariri east of the Nara (Khariri

Mojanwari) is a very large *dhand* with quite 8 feet of water. It is diamond-shaped, about 1 mile in length and half a mile at its widest. Owing to its depth and size, it seldom becomes sufficiently concentrated to deposit *chaniho*: it is the first *dhand* of those as yet considered which contains too much water to yield *chaniho*, but we shall find that there are many others in this class. It did, however, yield about 10 maunds in 1912-13. Its water had a specific gravity of 1.089, and contained 50.3 grams of Na_2CO_3 per litre.

- (10) **Dosewari** is an oval-shaped *dhand* on the N.W. flank of and close to the large Khariri *dhand*; it is in fact part of the Khariri basin, but separated by a narrow spit of low sand-bank. It is about 200 by 80 yards in size. It was dry at the time of my visit, but in other years had yielded small quantities of 2nd grade *chaniho*.
- (11) **Dheriun** is a *dhand* lying about $1\frac{1}{2}$ miles south of Khariri. It was dry and had given no yield at the time of my tour. I did not therefore visit it.
- (12) **Kalarwari** is half a mile south of Pir Nanga *dhand*. This is a small *dhand*, and was dry with no yield at the time of my visit.
- (13) **Virchora Sim**, called Whichonaro (possibly a misprint for Whichowaro) in the Vazir's list, is a large *dhand* almost divided into two by two promontories of sand which nearly meet in the middle. This *dhand* never yields *chaniho* itself, but supplies are occasionally obtained from the pools round its edges. It is inhabited by crocodile, which are here probably in water as brackish as they can stand. The specific gravity is 1.025; it contains 15.0 grams of Na_2CO_3 per litre, and 8.5 grams of NaCl per litre. Na_2SO_4 is present only in small quantity.
- (14) **Pharanwari Sim** (Pharanwala in list, and Sim Pharewaree in map) is a long narrow *sim* with probably about four or five feet of water. The *sim* itself does not yield *chaniho*, since the concentration is not sufficient, and the *dhand* is not sufficiently flat-bottomed to evaporate rapidly. At the south end there is a small pool isolated from the main *dhand*. Here concentration takes place, and a yield of *chaniho* amounting to about 200 maunds

per annum on an average is secured. This *dhand* is 1 mile east of Virchora and $2\frac{1}{2}$ miles south of Pir Nanga.

- (15) **Tikini** (marked Tur Teeknee on the map) is 2 miles W.S.W. of Pharanwari. This is a small unimportant *dhand*, and has always yielded only a very little *chaniho*.
- (16) **Achro Bitiro** (or, as in list, White Bitiro) is close to and E. of the *dhand* marked Achro Doobbo on the map. While Achro Doobbo is brackish, the small *dhand* Achro Bitiro close to it was completely dry and had yielded no *chaniho* in 1918. Compare the case of *dhands* Dosewari and Khariri described above.
- (17) **Paruwari** (or Paroowali of list, marked Paroowaree Tullee on map) is 2 miles S. of Tikini, and was completely dried up with no yield of *chaniho* at the time of my visit.
- (18) **Nanganwaro** or Nanganwala is about 1 mile west of Paruwari. It also was dry and had no yield.
- (19) **Chilhanwaro** (or Chilh as in list) is $\frac{1}{2}$ mile S. of Nanganwaro and not quite half a mile N. of Mitheri. It is a small oval-shaped *dhand* with very little water at the time of my visit, but with great abundance of efflorescent salt round its shore. An analysis of its *chaniho* will be found in Chapter VI. Its usual yield is about 300 maunds per annum.
- (20) **Mithri** (or Mitheri, marked Mithrejo Tur on map) is an oval *dhand* of very much the same size as Sukchaho, lying to the south of Chilhanwaro. It yields 2nd grade *chaniho* of which about 6,000 maunds were stacked round the *dhand*, this representing the season's output. The *dhand* was almost dry, but had a few patches of water here and there. There was great abundance of efflorescent salt (*kalar*) round its shores. This efflorescence, caused by the evaporation of *sim* or percolating water round the shores of the *dhand*, is washed into the *dhand* during the rains, and from the bittern thus produced *chaniho* crystallises out in the hot season (May or June). The water of this *dhand* had a specific gravity of 1.265, and contained 133.2 grams of Na_2CO_3 per litre.
- (21) **Galuwari** (Guloo Wali of list; spelt Gulloowaree Tullee on map) is $1\frac{1}{2}$ miles S.S.W. of Mithri. It was completely dry and had produced no *chaniho* at the time of my visit,

- (22) **Bujiwari** (Boogi of list, and Bojewaree Tullee of map) was also dried up, and produced no *chaniho* at the time of my visit.
- (23) **Lahuri**.—About $2\frac{1}{2}$ miles S. by W. of Galuwari at the spot marked Ghulam Chang jo Moqam are two *dhands*, both called Lahuri. The more westerly *dhand* is larger than Bagarwaro, the *dhand* to the east being smaller. Both were quite dry with no *chaniho*. They do not appear to have yielded since 1912-13, according to the statistics from Khairpur State. We have now described all the *dhands* west of the Nara in the Vazir's list. I may add one more *dhand* said to have yielded *chaniho* in former times during the rains; it is—
- (24) **Chambwari** (marked Chumb on the map). It was dry, and had not yielded anything at the time of my visit. This *dhand* is 1 mile S.E. of Mithri.

Reviewing now the *dhands* we have just described, it may be noted that three *dhands*, viz., Khariri, Virchora, and Pharanwari are too deep and contain too weak a bittern to deposit *chaniho* in the dry season: the *chaniho* is collected from isolated pools round their margins. Thirteen *dhands* never at any time during the rainy season immediately preceding my visit had enough water to dissolve the *kalar* around their shores and in their bed, and to re-deposit it in pure enough form to be marketed as *chaniho*. The names of these are Dabranwari, Dail, Chughari Kalarwari, Tarai Pir Nanga, Dosewari, Dheriun, Kalarwari, Achro Bitiro, Paruwari, Nanganwaro, Galuwari, Bujiwari, Lahuri. To these may be added a fourteenth, the unlisted Chambwari.

Only eight *dhands* were producing *chaniho* out of the list of 23. These are Bulahwari, Bagarwaro, Sukchaho, Chughari Chahe-wari, Tikini, Chilhanwaro, Mithri. Also Pharanwari which although it has excessive water, yields from an isolated pool at its south end.

In very wet years, it may be reasonably expected that many of the thirteen dry *dhands* above listed will again produce *chaniho*. On the other hand, the three large *dhands* with excessive water above-mentioned would not be likely to yield much *chaniho*, unless after a succession of exceptionally dry years. The seven producing *dhands* are those which produce in ordinary years. The best producer is probably Mithri; next in order Bulahwari, Sukchaho and Bagarwaro are good producers, all three fairly equal in merit;

the remaining three *dhands* are small and unimportant. I have stated that the season's output from Mithri was estimated at 6,000 maunds.

Having described the soda yielding *dhands* west of the Nara, I will now consider those larger or deeper *dhands*, which, although alkaline, never become sufficiently concentrated to yield trona, and have never become producers. I have not attempted to make a complete list of these *dhands*, some of which are not marked on the map. A full list could only have been made by a complete survey of the whole country, which would have greatly extended my tour. I give a list of the alkaline *dhands* seen in the course of my survey of the producing *dhands*. This list, though not complete, contains all the more important *dhands*, with analyses of the water in the case of the larger ones.

Of the *dhands* already described, three properly belong to the class now about to be described, *viz.*, Khariri, Virchora, and Pharanwari, because these three have never themselves yielded *chamiho*, which has only been collected from pools at their margins. Khariri and Virchora are the largest of the alkaline *dhands*. Analyses of their waters will be found in Chapter VI. Commencing with the most northerly, the list is as follows:—

- (1) **Bhitrawaro dhand**, west of and close to Bagarwaro, is about 3 furlongs in length, and contains brackish water probably not very highly concentrated.
- (2) **Bitrewari dhand**, between Sukchaho and Chughari Chahe-wari, is a brackish nearly circular *dhand* about $\frac{1}{4}$ mile in diameter.
- (3) **Khariri**, already described.
- (4) **Pir Naga or Pir Nanga**, 1 mile S.E. of Khariri, is an almost fresh water *dhand*; specific gravity 1.002; alkalinity calculated as sodium carbonate 1.2 grams Na_2CO_3 per litre.
- (5) **Nichora**, a small narrow *dhand*, $\frac{1}{4}$ mile in length, north of Virchora with brackish water.
- (6) **Virchora**, already described.
- (7) **Pharanwari**, already described.
- (8) **Dillahuwari**, a large *dhand* 1 mile long, half a mile broad to the south, narrow in the north, situated 1 mile south of Virchora. The water of this *dhand* had a specific

gravity of 1.024 and contained 12.8 grams of Na_2CO_3 and 3.5 grams of NaCl per litre.

- (9) **Gunjwari** (spelt Goonjwaree on map), not quite 1 mile S.W. of Bujiwari, are a pair of *dhands*, separated by a low spit of sand. That to the east is full of crocodile, and does not appear to be very brackish. The west *dhand* is about $\frac{1}{4}$ mile long, and not very broad. Its water has a specific gravity of 1.049, and contains 41.9 grams of Na_2CO_3 per litre. An analysis is given in Chapter VI.

Of the other *dhands* marked on the map, the majority are fresh or else slightly brackish.

Producing *dhands* In the Vazir's list already mentioned, the
east of Nara. following are the *dhands* east of the Nara :—

- | | |
|--------------------------|-------------------------|
| 1. Charakhanwala, Great. | 14. Kino Chaho. |
| 2. Ashrafwala. | 15. Metahari. |
| 3. Lahri, Great. | 16. Eastern Dabanwali. |
| 4. Saidahoo. | 17. Kakaranwala. |
| 5. Taraie Barkow. | 18. Matiwal. |
| 6. Khari Mojanwala. | 19. Lalri, Small. |
| 7. Khara Oker. | 20. Lambrow. |
| 8. Tarai. | 21. Hazari. |
| 9. Barkow. | 22. Buxahoo. |
| 10. Digh. | 23. Khabarwala. |
| 11. Jatoo Wali. | 24. Small Charaganwala. |
| 12. Lalri Lanbriwali. | 25. Gango. |
| 13. Bartkon. | 26. Mirwali. |

Here again the order of these names is neither geographical nor in descending order of production, but haphazard. I shall take the names in geographical order, beginning with the most northerly.

- (1) **Taraiwari** (Tarai, Turaewaree) is a small *dhand* yielding about 300—400 maunds of 3rd grade *chaniho*. It is 3 miles north of Jatuwari *dhand* (see below). Depth 1 foot.
- (2) **Mirwari** (Mirwali, Meerwaree) is 1 mile west of Jatuwari, and was dry at the time of my visit, having yielded no *chaniho* that season.

- (3) **Jatuwari** (Jutoo Wali of list, Jatoje Sim of map) is a long narrow *dhand* of small size, 200 yards by 30, but containing about 4 feet of water at the time of my visit. Owing to the excessive water, it had yielded no *chaniho* that season. A specimen of the water had a specific gravity of 1.19, and contained 143.4 grams of Na_2CO_3 and 59.1 grams of NaCl per litre.
- (4) **Khariri Mojanwari** is marked on the map as Kharwaree, but named Mojanwari to distinguish it from Khariri Chachwari west of the Nara. This is a long narrow *dhand* about $\frac{1}{4}$ mile east of Jatuwari, and resembling Jatuwari in shape, but still longer and larger. It is about 600 by 50 yards and has a depth of about 4 feet. *Chaniho* is only obtained from a small flat depression at the south end of the *dhand* separated from the main *dhand* by a bar of sand. The yield is about 600—700 maunds. An analysis of the *chaniho* will be found in Chapter VI. The water of the main *dhand* has a specific gravity of 1.118, and contains 88.7 grams of Na_2CO_3 per litre. An analysis of the water is also given in Chapter VI.
- (5) **Bartako** (Bartkon, Burtakowaree) is a mile and a half S.S.W. of Mirwari. Here are two circular medium-sized *dhands*, but both were completely dry, having yielded no *chaniho* that season.
- (6) **Metahari**, not marked on the map, is $1\frac{1}{2}$ miles S. of Jatuwari. Here are two very small *dhands* which lie to the immediate north of the more westerly of two *dhands* marked on the map as Lamrejee Sim. These two last-mentioned *dhands* are now known as Saidinwaro to the west and Khabarwaro to the east. The *Metahari dhands* lie to the immediate north of Saidinwaro. Third grade *chaniho* is obtained from *Metahari*, the yield being about 2,000—3,000 maunds. The depth is about 1 foot.
- (7) **Ubrand Dabranwari** (or Eastern Dabranwari) is so called to distinguish it from a *dhand* of the same name west of the Nara (see *ante*) which latter is known as Ulan Dabranwari or Western Dabranwari. This *dhand* is marked Wurenwaree on the map; the name Wurenwaree is however completely forgotten. Ubrand Dabranwari is 1 mile S. by W. of Bartako. It is a medium-sized

dhand, but was completely dry and had no *chaniho*, at the time of my visit.

- (8) **Lalri Sanhri** (or Lalri the Narrow, Small Lalri of list) is not marked on the map, but lies $\frac{1}{4}$ mile N.N.W. of the large *dhand* Lambro, marked Lambre-waree on the map. This *dhand* is a small narrow *dhand*, 100 by 30 yards, and 1 foot deep. It yields 3rd grade *chaniho*, of which there were about 400 maunds.
- (9) **Lalri Lambre-wari** (Lalri Lanbriwali of list) is not named on the map but is shown as a small oval *dhand* north of Lambrewari. It is about 120 yards long by 50 broad, and has about 2 feet of water. It yields first-grade *chaniho*, of which there were about 200 maunds.
- (10) **Lambro** (or Lambre-wari.)—This is the largest *dhand*, except Virchora, of all the producing *dhands* of Khairpur, and the second greatest producer, Barko being the greatest. It does not however yield from the northern half of the *dhand*, where there are about six feet of water. If we imagine the *dhand* to be divided into three parts from north to south, then the southern third part of this *dhand* is separated from the northern two-thirds by a sunken bar of sand, which is uncovered only in the hot weather. It is from this southern third that *chaniho* is collected. This is second-grade in quality, and there were about 8,000—9,000 maunds present. The water of Lambro has a specific gravity of 1.081, and contains 19.0 grams of Na_2CO_3 per litre. Analyses of the water and the *chaniho* will be found in Chapter VI. Lambro is about 1 mile in length, and three furlongs broad.
- (11) **Lalri Wadi** (or Great Lalri), is a medium-sized *dhand* situated at the northern end of the *tali* marked Lagrewaree on the map. It is less than $\frac{1}{4}$ mile distant from Lambro, and lies to the west. When I saw it, it had about 1 foot of water, and had produced that season from 3,000—4,000 maunds of *chaniho* of first grade quality. An analysis of the *chaniho* is given in Chapter VI.
- (12) **Ganjawari** (Gango of list) is a long narrow *dhand*, about 500 by 80 yards. It contained about 1 foot of water, in which plenty of *chaniho* was crystallising. It produced

in the season of my visit between 3,000—4,000 maunds of first-grade *chaniho*. This *dhand* is marked on the map and is about 1 mile S.W. of Lambro. Its water contained 91.5 grams of Na_2CO_3 and 92.5 grams NaCl per litre. An analysis of its water and of its *chaniho* will be found in Chapter VI.

- (13) **Matiwaro** (marked in map as Futlowaree Sim) is an oval-shaped *dhand* of medium size, length about $\frac{1}{4}$ mile. It had about 4 feet of water in it at the time of my visit. Owing to this excessive depth of water, no *chaniho* had been obtained that season. This *dhand* is about $1\frac{1}{2}$ miles S.S.W. of Ganjawari.
- (14) **Khara Okar** (marked on map as Khara Oogurwaree Sim) is about two miles S. by W. of Matiwaro *dhand*. There are here two medium-sized circular *dhands*. Both of these contained excessive water, and for that reason no *chaniho* was obtained from them that year. A specimen of water from the northern *dhand* had a specific gravity of 1.151 and contained 118.4 grams of Na_2CO_3 per litre.
- (15) **Khabbarwaro** (marked Khubburwaree on map) is 1 mile east of Khara Okar, and is a long narrow *dhand*, 500 by 40 yards approximately. The *dhand* contained a little water. The *chaniho* yielded is said to be third-grade. An analysis is given in Chapter VI.
- (16) **Kakaranwaro** (marked Kuhrunwaree Sim on map) is a large alkaline *dhand* which has never yielded *chaniho* owing to excess of water. To the north, there is a small *dhand* covering not quite an acre, with about 1 foot of water. About 400—500 maunds of *chaniho* were seen; this was of third-grade quality. This *dhand* is half a mile N.N.E. of Khabbarwaro.
- (17) **Drigwari** (Digh of Vazir's list) is 2 miles W.S.W. of Khara Okar. There are three completely dry *dhands* here. No *chaniho* was obtained this year. An analysis of the *kalar* efflorescence is given in Chapter VI.
- (18) **Ashrafwaro**.—This *dhand* was also completely dry. An analysis of the *kalar* efflorescence is given in Chapter VI. Ashrafwaro is about 1 mile S.E. of Drigwari.
- (19) **Kino Chaho**.—This is marked as Chuhwaro Put on the map. In a list dated 1899, the *dhand* is called Tat

- Adlahu Chaho. It is completely dry and only *kalar* is visible. An analysis of the *kalar* is given in Chapter VI. Kino Chaho is about half a mile south of Ashrafwaro. In former years it produced fairly pure *chaniho*, an analysis of 1899 showing only 2 per cent. of NaCl in the *chaniho* of this *dhand*.
- (26) **Tarai Barko**.—This is a small *dhand* to the immediate north of Barko. It was dried up, and no *chaniho* was obtained from it.
- (21) **Barko** (marked on map as Bukarukhio jo Sim) is the largest producer of all the *dhands*, yielding from 10,000 to 11,000 maunds of first grade *chaniho* per year. From 1913 to 1915, it did not yield, presumably owing to excess of water. Barko is 2 miles S. by W. of Khara Okar, and is an oval-shaped *dhand*, about 400 by 200 yards in size. It contains about 3 feet of water. All round the *dhand* there is abundant *kalar* efflorescence. A specimen of the water had a specific gravity of 1.157, and contained 106.0 grams of Na_2CO_3 per litre. An analysis of the *chaniho* and water is given in Chapter VI.
- (22) **Buxahu**, $\frac{3}{4}$ mile east of Barko, is named on the map Ram Rahoo jo Koomb. This name of Ram Rahu is now forgotten, but a small *dhand* near Matahari is now called Ram Rahu. Buxahu is a long narrow *dhand*, about 500 yards by 30 yards. It contains first grade *chaniho*, of which an analysis is given in Chapter VI. The water was about 1 foot deep. There was very little *kalar* round its margin.
- (23) **Saidahu**, 2 miles south of Barko, was completely dry at the time of my visit, and yielded no *chaniho*. An analysis of its *kalar* is given in Chapter VI.
- (24) **Charakhanwaro Wado**, and (25) **Charakhanwaro Nandho**, (or Charakhanwaro the large, and the small) are both about 1 mile south of Saidahu. Both these *dhands* were completely dry, and yielded no *chaniho* that season. An analysis made in 1899 on a specimen of *chaniho* from one of these *dhands*, shows only 2 per cent. of NaCl. The analysis does not state from which *dhand* the *chaniho* came.

- (26) **Hamari** is marked on the map as Huzaree jo Chhuo. There are here two *dhands*, one a large *dhand* of sweet water, and a small *dhand* to the north in which *chaniho* accumulates. The large fresh water *dhand* had water, but the small *dhand*, from which *chaniho* has been obtained in former years was completely dry.

Of the twenty-six *dhands* in the above list, twelve only produced *chaniho*, viz., Taraiwari, Metahari, Lalri Sanhri, Lalri Lambrewari and Lalri Wadi, Khariri Mojanwari, Lambro, Ganjawari, Khabbarwaro, Kakaranwaro, Barko, and Buxahu. Three *dhands* had excessive water, viz., Jatuwari, Matiwari, and Khara Okar. Eleven *dhands* were dry, viz., Mirwari, Bartako, Ubrand Dabranwari, Drigwari, Ashrafwaro, Kino Chaho, Tarai Barko, Saidahu, Charakhanwaro Wado and Nandho, and Hazari. Three of the producing *dhands*, viz., Khariri Mojanwari, Lambro, and Kakaranwaro are closely connected with larger *dhands* or deeper extensions of the same name which do not, owing to excess of water, yield *chaniho*.

Of these *dhands* by far the best producer is Barko; next in order of merit is Lambro, next Ganjawari; these three are superior to any *dhands* west of the Nara. Lalri Wadi, Metahari, Khabbarwaro, and Buxahu are medium producers, ranking with Bulahwari, Sukchaho and Bagarwaro west of the Nara. Taraiwari, Khariri Mojanwari, Lalri Lambrewari and Sanhri, and Kakaranwaro are small producers of much less importance. The production however varies from year to year according to the rainfall.

Of the larger *dhands*, which owing to depth and size, have never deposited *chaniho*, the most northerly *dhand* examined is—
 Large alkaline *dhands* east of Nara.

- (1) **Khariri Mojanwari**, main *dhand*, already described.
- (2) **Sarwari** (marked Sarwaree Sim on map) is $1\frac{1}{2}$ miles S.W. of Khariri Mojanwari. Sarwari is an oval-shaped *dhand*, about 3 furlongs in length, with 4 or 5 feet of water. The water has a specific gravity of 1.049, and contains 34.3 grams of Na_2CO_3 per litre.
- (3) **Moqamwari** (marked Mookamwaree Sim) lies a furlong to the east of Sarwari, and is about the same length although perhaps a trifle narrower. The depth of both *dhands* appears to be about the same. The specific

gravity of Moqamwari is 1.127, and the water contains 105.9 grams of Na_2CO_3 per litre.

- (4) **Ram Rahu dhand**, west of Metahari, and close by is a small alkaline *dhand*, narrow and deep (about 4 feet) from which no *chaniho* has as yet been obtained. Its name is not shown on the map.
- (5) **Saidinwaro** is an oval *dhand*, $\frac{1}{2}$ mile in length, with 3 or 4 feet of water, lying immediately south of Metahari. It is named Lumrejee Sim on the map, the name being written over this and another *dhand* to the east. Lumrejee presumably implies merely "one of the Lambro group," and this *dhand* might be called Saidinwaro Lambreji. Its water has a specific gravity of 1.119, and contains 47.4 per cent. of Na_2CO_3 per litre.
- (6) **Khabbarwaro Lambreji**.—This is the easterly of the two *dhands* marked Lumrejee on the map. It is named Khabbarwaro by the inhabitants, but should not be so called without adding Lambre ji, in order to distinguish it from the producing *dhand* Khabbarwaro, which lies between Khara Okar and Kakaranwaro. This *dhand* is narrow and is nearly $\frac{3}{4}$ mile long, but broadens out slightly at its northern end. Its water has a specific gravity of 1.089, and contains 53 grams of Na_2CO_3 per litre.
- (7) **Lambro**.—The northern two-thirds of this *dhand* never yields *chaniho*. The *dhand* has already been described.
- (8) **Usar** (marked Oosarwaree Sim on the map) is two miles west of Lambro. It is an oval-shaped *dhand*, $\frac{3}{4}$ mile long, and $\frac{1}{4}$ mile broad, with a small island in the middle. It had about five feet of water. The specific gravity was 1.031, and the water contained 20.1 grams of Na_2CO_3 per litre.
- (9) **Kakaranwaro**, main *dhand*. This is an oval medium-sized *dhand*, distinctly alkaline, but has never yielded *chaniho*, which is obtained only from a small *dhand* to the north.
- (10) **Motranwaro** is a *dhand*, long and narrow, and of much the same dimensions as Buxahu (500 by 30), but has never yielded *chaniho*. It is nevertheless highly alkaline, although not sufficiently flat-bottomed to evaporate

sufficiently in the dry season. It had about four or five feet of water. The specific gravity was 1.189, and the water contained 123.6 grams Na_2CO_3 per litre.

Other *dhands* nearer to the Nara, such as Bar Ramo or Bar Ramewari, and Pokhulwaro west of Sarwari are fresh. The *dhands* between Usar and the Nara are also fresh.

In concluding this chapter, I give below tables summarising the results of my survey. I reserve questions of production for a future chapter. From the tables given it will be seen that the season 1918-19 was inclined to be a dry one in the Nara region, although not excessively so, for it must not be forgotten that besides the effect of dry seasons, the gradual desiccation of the Nara region owing to the control of the floods, is having some effect upon certain *dhands*. Possibly Drigwari, Ashrafwaro, Kino Chaho, Lahuri, and perhaps one or two more are permanently dry, or at any rate will never have enough water to dissolve the *kalar*, and recrystallise it out as *trona*. Other *dhands* are dry owing to the scanty rainfall, and it is to be hoped will again yield in wetter years. But in wetter years, some of the *dhands* which now produce will pass into the class of *dhands* with excess of water. It is exceedingly unlikely that Lambro for instance would yield in a very wet year. It is thus apparent that *chaniho* is obtained from a different set of *dhands* each year, according to the rainfall, and that it would be impossible for all the *dhands* to produce simultaneously.

From table II it will be seen that there are at least 18 *dhands* (probably more, for the list is not complete) from which *trona* could be obtained by artificial methods.

TABLE I.—Table showing the state of the Khairpur *dhands*, Nara region, as they were in season 1918-19.

—	Producing.	Dry.	Excessive water.
DHANDS WEST OF NARA.	Bulahwari . .	West Dabranwari .	Khariri.
	Bagarwaro . .	Dail . .	Virohora.
	Sukchaho . .	Chughari Kalarwari	
	Chughari Chahewari	Tarai Pir Nanga .	

TABLE I.—Table showing the state of the Khairpur dhands, Nara region, as they were in season 1918-19.

— —	Producing.	Dry.	Excessive water.
DHANDS WEST OF NARA.	Tikini . . .	Dosewari.	
	Chilhanwari . .	Dheriun.	
	Mithri . . .	Kalarwari.	
	Pharanwari* . .	Achro Bitiro.	
		Paruwari.	
		Nanganwaro.	
		Galuwari.	
		Bujiwari.	
		Lahuri.	
		Chambwari.	
TOTALS .	8	14	2
DHANDS EAST OF NARA.	Taraiwari . . .	Mirwari . . .	Jatuwari.
	Metahari . . .	Bartako . . .	Matiwaro.
	Khariri Mojanwari*	East Dabranwari .	Khara Okar.
	Lambro . . .	Drigwari . . .	
	Lalri Sanhri . . .	Ashrafwaro.	
	Lalri Lambrewari .	Kino Cháho.	
	Lalri Wadi . . .	Tarai Barko.	
	Ganjawari . . .	Saidahu.	
	Khabbarwaro . .	Charakhanwaro Wado.	
	Barko . . .	Charakhanwaro Nandho.	
	Kakaranwaro* . .	Hazari.	
	Buxahu.		
TOTALS .	12	11	3
GRAND TOTALS	20	25	5

NOTE.—Those dhands which are marked* produce *chaniho* from isolated portions, while there is excessive water in their main dhands.

TABLE II.—*List of alkaline dhands which have never produced, owing to excessive depth and insufficient concentration of water. Those dhands marked* yield from isolated portions, but not from the main dhands*

DHANDS WEST OF NARA	Bhitrewaro.	
	Bitrewari.	
	Khariri*	
	Nichora.	
	Virchora*	
	Pharanwari*	
	Dillahuwari.	
	Gunjwari.	
TOTAL		8
DHANDS EAST OF NARA	Khariri Mojanwari.*	
	Sarwari.	
	Moqamwari.	
	Ram Rahu.	
	Saidinwari.	
	Khabbarwari Lambreji.	
	Lambro.*	
	Usar.	
	Kakaranwari.*	
	Motranwari.	
TOTAL		10
GRAND TOTAL		18

NOTE.—Khariri and Virchora are asterisked, since they yielded from isolated portions in former years. They did not yield in season 1918-19, owing to excess of water.

CHAPTER III.

THE KHAIRPUR STATE, KOT JUBO REGION.

It has been already explained that those *dhands* which lie east of Kot Jubo are maintained by the *sim* or Introductory. percolating water which escapes from beneath the two great sand-plateaux or *dra-ins*, named the Pur Chandar and the Sano-i *dra-in* respectively. The belt of country covered by *bhit* and *tali* lying between these two *dra-ins* contains the majority of the *dhands*, and it is with this belt that our description must commence. It will be convenient to travel over this belt from south to north, and then to describe the outlying *dhands*. Here again the *dhands* fall into two sections, viz., A. *Dhands* lying between the two great *dra-ins*, and B. *Dhands* on the outer margins of the *dra-ins*.

I visited this area in company with Mr. E. L. Thurley, and spent three days from January 14th to 16th there. In this brief time, I was unable to visit all the *dhands*, but I succeeded in obtaining specimens from the more distant ones through the assistance of Mr. Mahommed Khan, who sent off messengers with bottles to be filled with the bitterns.

Two lists of the producing *dhands* of the Kot Jubo region are in my possession. One list dating from 1899 was obtained from an old file on *chaniho* in the possession of Mr. Thurley. This list gives also the percentage of NaCl in the *chaniho* of each *dhand*. I add to the list a statement of the present state of each *dhand*, i.e., whether dry, producing, or containing excessive water. The second list is that given by the Vazir, already mentioned. The earlier list is reproduced below :—

Name of <i>dhand</i> .	Percentage of NaCl.	Present condition (1918).
1. Rojewaro	5	Dry.
2. Abdul Rahim	9	Produced 200 maunds 1918-19.
3. Letan Abdul Rahim	3	Dry.

Name of <i>Dhand</i> .	Percentage of NaCl	Present condition.
4. Laniwari	76	Excessive water.
5. Kot Koro*	5	Excessive water.
6. Gidhar-warō	19	Dry.
7. Padrio	39	Dry.
8. Jaran-warō	3	Dry.
9. Wat-warō	64	Dry.
10. Waran-warō	11	Dry.
11. Matran-warō	17	Dry.
12. Boran-warō or Bowan-warō	38	Excessive water.
13. Manohur	76	Dry.
14. Garho Got*	4	Excessive water.
15. Suji Nandhi	33	Producing.
16. Suji Wadi	59	Producing.
17. Bambalui Nandhi*	39	Dry.
18. Bambalui Wadi*	4	Excessive waters.
19. Kandiwarō*	21	Excessive waters.
20. Rahimwarō	5	Dry
21. Achro	13	Dry.
22. Sano-i Nandhi	2	Dry.
23. Sano-i Wadi*	2	Excessive water.
24. Sano-i Narwari*	8	Excessive water.
25. Jhando-i Wadi*	1	Excessive water.
26. Jhando-i Nandhi	3	Dry ?
27. Gandhi*	8	Excessive water.
28. Gapnum or Gubno	7	Excessive water.
29. Ahirowarō	8	Excessive water.
30. Kalbuwarō*	1	Excessive water.

Name of <i>Dhand</i> .	Percentage of NaCl.	Present condition.
31. Pharanwaro	1	Producing.
32. Gadan-wari	4	Producing.
33. Narwaro or Nainwaro	3	Producing.
34. Ganorwaro or Ganwarwaro	1	Producing.
35. Pakhyaro*	1	Producing.
36. Khairo or Kharro*	1	Excessive water.
37. Bhaun	1	Dry.

Of the above 37 *dhands* those marked with an asterisk appear in the Vazir's list, dated 2nd November 1918, mentioned above. In addition to these the Vazir's list gives eight other *dhands*, viz., Laiwaro, Gabanwaro Rait Pario Sano-i Garhi, Nau Rait, Dabho, Padru, and Sano-i Kotenwari. These in addition to the eleven *dhands* marked with an asterisk, number 19 in all, which was the total number on the Khairpur State list in 1918, 26 of the 37 *dhands* having dropped off the list in the course of twenty years while only eight new *dhands* were added. The spelling of the Vazir's list differ from that of the first list of 1899. Bambalui is spelt Niblowie, while the name Phuloowala according to Mr. Mahommed Khan, denotes the *dhand* properly known as Kalbuwaro. The other differences in spelling are trifling.

We may add the eight new *dhands* of the Vazir's list to those previously given, as follows:—

Name of <i>Dhand</i> .	Present condition.
38. Laiwari	Producing.
39. Gabanwaro	Excessive water.
40. Rait Pario	Excessive water.
41. Sano-i Garhi	Excessive water.
42. Nau Rait	Excessive water.

Name of <i>Dhand</i> .	Present condition.
43. Dabho	Excessive water.
44. Sano-i Koten-wari	Excessive water.
45. Padru	Excessive water.

Of the 45 *dhands* above listed, the condition in season 1918-19 was as follows:—

Nine *dhands* were producing.

Fifteen *dhands* were dry.

Twenty-one *dhands* had excessive water.

All the dry *dhands* were *dhands* which had dropped off the Khairpur lists since 1899. They all lie to the north of the *dra-ins* of Pur Chandar or Sano-i. Probably in the course of years the desert sand has blown over much of the land to the north of the *dra-ins*, filling up the hollows in many places, so that *dhands* are now smaller or entirely dried up in this area. Mr. Mahommed Khan informed me that the Pur Chandar *dhand*, formerly supposed to be fathomless, has grown smaller of late years by the encroachment of the desert sand, and that the local people no longer place any credence in the old legends of its great depth.

The fact then that fifteen *dhands* were dry has nothing to do with the rainfall of 1918. If this fact is recognised it will be seen that in the Kot Jubbo area, the season immediately preceding my visit must have been an excessively wet one, since only nine *dhands* produced, and the rest of the recently worked *dhands* contained excessive water. But the most curious feature is that of the nine producing *dhands* six, *viz.*, Abdul Rahim, Suji Nandhi, Suji Wadi, Pharanwaro, Gadanwaro, Ganwarwaro, are names which occur in the old list of 1899, but are not found in the recent list of 1918. This means that the very excessive rainfall caused water to collect in several of the old usually dry *dhands* which again, after a lapse of years, yielded *chaniho*.

- (1) Pakhyaro was by far the largest producer in season 1918-19, although there was an excess of water in the *dhand*, so that *chaniho* was obtained only from the south

Producing *dhand*
between the two *dra-ins*.

end, while the north part did not yield. Pakhyaro is the most southerly of the *dhands*, being $\frac{1}{2}$ mile long and about 100 yards broad (see plates 2 and 7). There is about 2 feet of water. The specific gravity was 1.104, and the water contained 87.4 grams of Na_2CO_3 , and 22.7 grams of NaCl per litre. Complete analyses of the water and the *chaniho* of this *dhand* are given in Chapter VI. There were about 5,000 maunds of *chaniho* of first grade quality stacked on the south shore at the time of my visit.

- (2) **Ganwarwaro**.—One of the old *dhands*, dry during several years, which, owing to the excessive rainfall, yielded in the season of my visit. The *dhand* is about $\frac{1}{4}$ mile N.N.E. of Pakhyaro, and is very small (50 by 50 yards about) being circular in shape, and containing about 1 foot of water. About 500 maunds of third grade *chaniho* were obtained from it. An analysis of the *chaniho* is given in Chapter VI.
- (3) **Nainwaro or Narwaro**.—This is 1 furlong N.N.E. of Ganwarwaro, and is still smaller (25 by 50 yards). It is also one of the old *dhands* of the 1899 list, which remained dry for some years, and again yielded in this excessively wet year. About 200 maunds of third grade *chaniho* were obtained. An analysis is given in Chapter VI.
- (4) **Gadanwari dhand**.—In the Survey map reproduced in plate 16, it will be seen that a *dhand* north of Pakhyaro is marked Guddarwaree. This *dhand* is not correctly named, its real name is Lai-wari, while Gadanwari lies in the *tali* immediately to the west. Gadanwari consists of two *dhands*, one to the north and one to the south, and separated by a narrow bar. Each *dhand* is about 100 by 25 yards, and has about 2 feet of water. These two Gadanwari *dhands* are about 300 yards west of Lai-wari (marked Guddarwaree on the map). About 800 maunds of second grade *chaniho* was obtained from the south *dhand*, and 400 maunds from the north *dhand* in season 1918-19. The *dhands* are mentioned in the old list of 1899, but not in the list of 1918. The specific gravity of the water of the south *dhand* was 1.051; there were 35.0 grams of Na_2CO_3 and 14.3 grams of

NaCl per litre present. An analysis of the *chaniho* of the north *dhand* is given in Chapter VI.

- (5) **Laiwari** is about $1\frac{1}{4}$ miles N.N.E. of Pakhyaro, and is a long narrow *dhand*, about 5 furlongs in length. It is not mentioned as a producer in the old list of 1899, and evidently had then too much water. At the time of my visit there were from 3 to 4 feet of water, and although there is abundant sodium carbonate in the lake, only about 100 maunds were extracted. The water had a specific gravity of 1.115, and contained 100.3 grams of Na_2CO_3 and 24.9 grams of NaCl per litre. On the Survey of India map this *dhand* is wrongly named Guddarwaree.
- (6) **Pharanwaro**, mentioned in the list of 1899, but not in that of 1918, is a very tiny *dhand*, about 30 by 6 yards and is situated immediately north of the now dried up depression marked on the map of 1860 as Leware je Dhund. About 50 maunds of third grade *chaniho* were obtained in season 1918-19.
- (7) **Kalbuwaro** is so named in the list of 1899, but in that of 1918 there is a *dhand* named Phuloowala, which, according to Mr. Mohammed Khan, is a corruption of the true name Kalbuwaro. It is marked on the Survey map, but not named, and is the *dhand* lying immediately west of that marked as Savaree je Dhund. The *dhand* is now a small one, about 100 by 30 yards, and yielded no *chaniho* owing to excess of water in season 1918-19. In the preceding year, it yielded about 300 maunds of third grade *chaniho*.
- (8) **Gapnum** is the *dhand* marked as Gubno jo Dhund in the Survey map. It is mentioned among the producing *dhands* in the old list of 1899, but not in that of 1918. It is a small *dhand*, but has excess of water, and does not yield *chaniho*.
- (9) **Ahirowaro**, also mentioned in the list of 1899, but not in that of 1918, appears to be the *dhand* marked Jhungunwaro Dhund on the map. I could not reconcile the map in this portion with the actual country. North-east of the *dhand* marked as Savaree je Dhund, there is a *dhand*

marked on the map as Turhan je Dhund. But this *dhand* is also known as Savari *dhand*, the name being applied to both with the prefixes East and West, or Ubrand Savari and Ulan Savari. The name Turhan is applied to a *dhand* about $\frac{1}{2}$ mile north of Ulan Savari. We may either say that the *dhand* now known as Turhan is not marked on the map or that the *dhand* lying between Jhungunwaro and Gubno is intended to indicate this *dhand*, but that it has been wrongly placed too far to the north. Ahirowaro and Gubno are small unimportant *dhands*.

- (10) **Achro** is west of the large Sahai *dhand*, and close by. It is mentioned in the 1899 list, but is now dry.
- (11) **Padru** is the northern of the two small *dhands* immediately west of Machoe or Mujoe je Dhund (see map). It is not mentioned in the 1899 list, but occurs in that of 1918. It is a long narrow *dhand*, about half a mile in length by about 80 yards across, and had a depth of about 5 to 6 feet of water. Owing to excess of water it yielded no *chaniho* in 1918-19. The water had a specific gravity of 1.029, and contained 20.1 grams of Na_2CO_3 and 6.2 grams of NaCl per litre.
- (12) **Kandiwaro** (or Kandriwaro) is mentioned in both lists, and lies a furlong or so west of Padru. It is about 150 by 50 yards and had about 3 feet of water. It had excessive water and yielded no *chaniho* in season 1918-19, but in the previous season its *chaniho* was second grade. There was abundant *kalar* at the south end of the *dhand* of which a specimen was taken, the analysis of which is given in Chapter VI. Its water had a specific gravity of 1.025, that is almost the same as Padru, and contained 14.9 grams of Na_2CO_3 and 11.1 grams of NaCl per litre.
- (13) **Bambalui Wadi**.—This is mentioned in both lists, but is called Niblowie in that of 1918. It is about 1 mile N. by W. of the *dhand* marked Noon Khan je Dhund. It is a large dry *dhand* with a pool at its south end about 60 by 20 yards in size. In former years it yielded third grade *chaniho*, but none in 1918-19. The water had a specific gravity of 1.084, and contained 58.4 grams of Na_2CO_3 and 28.9 grams of NaCl per litre.

- (14) **Bambalui Nandhi**.—This lies north of Bambalui Wadi. It is now dry. The name occurs in the old 1899 list, but not in that of 1918.
- (15) **Rahimwaro** is north of Kandiwaro and close by. It is now dry.
- (16) **Gidharwaro**, (17) **Padrio**, (18) **Jaranwaro**, (19) **Watwaro**, (20) **Waranwaro**, and (21) **Matranwaro** are all three miles or less north of the northern of the two *dhands* marked Chundroee jo Dhund. The name Chundroee should only be applied to the southern, the name of the northern being Leyara. All these *dhands* (16) to (21) are now dry, and are not mentioned in the 1918 list.
- (22) **Boranwaro** (or Bowanwaro).—Mentioned in the 1899, but not in the 1918 list. This *dhand* lies between Leyara and the group of *dhands* numbered (16) to (21). It had excessive water according to Mr. Mohammed Khan.
- (23) **Manchur**, 1 mile north of Leyara, is mentioned in the list of 1899, but has since dried up.
- (24) **Garho Got**.—Mentioned on both lists, is a small *dhand* between the two *dhands* marked Chundroee on the map, that is, between Leyara and Chundroee (since the northern Chandroi is wrongly so named, and should be marked Leyara). It is a circular *dhand* with a diameter of about 60 or 70 yards. It contained 2 to 3 feet of water, and had yielded no *chaniho* that season. Its water had a specific gravity of 1.060, and contained 47.1 grams of Na_2CO_3 and 13.2 grams of NaCl per litre.
- (25) **Kharowaro** is a *dhand* not mentioned in either list. It lies very close to and immediately north of Chandroi (that is the southern of the two *dhands* marked Chundroee). It is very small, about 20 by 20 yards. It produced 50 to 60 maunds of third grade *chaniho* during season 1918-19.
- (26) **Suji Nandhi**, and (27) **Suji Wadi** are at the north-east end of Chandroi, quite close to Kharowaro. I saw only one pool nearly dry, about 50 by 15 yards in size. I do not know whether this was Suji Nandhi or Wadi. About 300 maunds of second grade *chaniho* had been obtained. An analysis is given in Chapter VI. The two Suji

dhands and Kharowaro are to be regarded as isolated pools of Chandroi, and are only separated from the large *dhand* by very narrow bars.

The 27 *dhands* given above complete the list of *dhands* from which *chaniho* has been obtained, and which lie between the *dra-ins* of Pur Chandar and Sano-i.

Owing to the limited time at my disposal, none of the *dhands* on the outer margins of the *dra-ins* were visited, with the exception of the four Sanoi *dhands*, which were visited by Mr. Thurley. Since none of the outlying *dhands*, with the exception of Abdul Rahim had yielded any trona in the year of my visit, it did not appear necessary to do more than examine the water of the more important ones. Mr. Mahommed Khan, however, procured specimens of the bitterns for me, and thus saved me from the necessity of collecting them myself.

I shall consider the *dhands* on the outer margins of the Sanoi *dra-in*, beginning with the most southerly.

(28) **Kharro**, mentioned in both lists, yielded *chaniho* containing only 1 per cent. of NaCl in 1899, but had excessive water in the season of my visit. Kharro is marked on the map as Khure jo Tith, and is $12\frac{1}{2}$ miles E.S.E. of Pakhyaro. It is about 2 acres in extent, and has about 2 feet of water. The specific gravity was 1.069, and the quantities of salts present were Na_2CO_3 — 53.8 grams per litre, NaCl — 19.3 grams per litre.

(29) **Jhando-i Wadi**, and (30) **Jhando-i Nandhi**. Mr. Mahommed Khan knew of the existence of only one *dhand* named Jhandoi, presumably Jhandoi Wadi, the other having possibly become dry within the past twenty years. This Jhandoi is mentioned in both lists. It had excessive water in 1918 and produced no *chaniho*. It is reported to be a small *dhand* 30 by 30 yards with about 2 feet of water. It lies $8\frac{1}{2}$ miles due east of Gapnum or Gubno and is marked on the map as Jundoe-warō Koothee. The water has a specific gravity of 1.090, and contains 60.8 grams of Na_2CO_3 and 29.6 grams of NaCl per litre.

- (31) **Dabho** is said to be 1 mile north of Jhandoi, and is about 1 acre in extent with about 2 feet of water. It is not marked on the map and its name is not given in the list of 1899. It had excessive water in 1918.
- (32) **Gandhi** (or Gandhi-war, marked Ghundeewaro Tith on the map), mentioned on both lists, is $6\frac{1}{2}$ miles east of Gapnum and 2 miles W. by S. of Jhandoi. Its *chaniho* had 8 per cent. of NaCl in 1899. In 1918 there was excess of water and no *chaniho*. It is about 3 acres in extent, and was reported to have 2 to 3 feet of water. The specific gravity of the water was 1.087, and there were 69.0 grams of Na_2CO_3 and 27.8 grams of NaCl present per litre.
- (33) **Sanoi Nandhi**.—This is one of the group of Sanoi *dhands*, situated $4\frac{1}{4}$ miles east of Sahai (Sahae je Dhund of map). Sanoi Nandhi is now dry, although it yielded in 1899. It lies to the immediate north of the Sanoi Wadi, which see.
- (34) **Sanoi Wadi** is mentioned in both lists. It is the western of the two long narrow *dhands* marked on the map Sunnohee jo Tith. Mr. Thurley reports that the *dhand* is about 200 yards long by 10 yards wide, with a depth of 3 feet, and that there was a heavy coating of efflorescent salt on its shores. The water had a specific gravity of 1.048, and contained 34.8 grams of Na_2CO_3 and 7.0 grams of NaCl per litre. Owing to excess of water, no *chaniho* was obtained in 1918.
- (35) **Sanoi Kotenwari**, (36) **Sanoi Garhi**, and (37) **Sanoi Narwari** were in 1918 all one *dhand*, namely, the eastern of the two marked on the map as Sunnohee jo Tith. In drier years this *dhand* becomes separated into three by the emergence above water level of two bars. Of these three *dhands*, that to the south is Kotenwari, that in the middle is Garhi, and that to the north is Narwari. The whole three *dhands* are about 260 yards in length. Mr. Thurley gives the dimensions as follows:—
- | | |
|---------------------|------------------------------|
| Kotenwari | 50 by 10 yds. ; depth 4 ft. |
| Garhi | 60 by 10 yds. ; depth 3 ft. |
| Narwari | 150 by 15 yds. ; depth 5 ft. |

Mr. Thurley collected samples of water from the three sections of the then united *dhands*. The following are the results of the

TABLE III.

	Sp. Gr.	Na ₂ CO ₃ , grams per litre.	Na ₂ SO ₄ , gms. per litre.	NaCl, gms per litre.
Sanoi Koteuwari . . .	1.033	22.8	3.1	6.1
Sanoi Garhi . . .	1.037	26.1	3.5	7.0
Sanoi Narwari . . .	1.046	33.7	4.4	9.1

The proportion of carbonate to chloride in these three *dhands* is nearly the same, *viz.*, in Koteuwari 3.73 : 1, in Garhi 3.73 : 1, in Narwari 3.70 : 1. It will be seen that while the solution is weaker in the south, the proportions of the salts do not greatly vary.

- (38) **Gabanwaro** is mentioned in the list of 1918, but not in that of 1899, probably because it then had excessive water. Gabanwaro is 5 miles N.W. of Pur Chandar *dhand*, and is the easterly of the two *dhands* shown on the map as lying immediately north of a *dhand* marked Dhoon Khan jo Doobhan. Gabanwaro is about 1 acre in extent, and had about 3 feet of water in 1918, having yielded no *chaniho* that year. The water had a specific gravity of 1.041, and contained 21.1 grams of Na₂CO₃ and 24.9 grams of NaCl per litre.
- (39) **Rojewaro**, mentioned in the list of 1899, is west of Gabanwaro but has been dry for many years.
- (40) **Abdul Rahim** lies north of and close to Rojewaro, and is mentioned in the list of 1899, but not in that of 1918. It has been dry for several years, but owing to the excessive water of 1918, again yielded about 200 maunds. (2) and (3) are similar resuscitated *dhands*, see *ante*.
- (41) **Letan Abdul Rahim**, mentioned in the 1899 list, lies north of and close to Abdul Rahim. It has been dry for several years.
- (42) **Laniwari**, a *dhand* which in 1899 yielded a deposit containing 76 per cent. of chloride, lies about 2 miles N. of

Dhoon Khan jo Doobhan, not far from Lanehwalee Bhit marked on the map. Laniwari had excessive water in 1918, but in any case the lake is probably too saline to yield *chaniho*. The bottle containing the specimen of water from the *dhand* was broken and no test made.

- (43) **Nau Rait**.—This *dhand* is mentioned in the list of 1918, but not in that of 1899, and is a comparatively new producer. Mr. Mahommed Khan describes it as situated 4 miles W.N.W. of the *dhand* marked Kharoree je Dhund on the map, which latter *dhand* lies $2\frac{1}{2}$ miles N. W. of Dhoon Khan jo Doobhan. It is about 2 acres in extent with about 3 feet of water, the water in 1918 being in too great excess to deposit *chaniho*. The water had a specific gravity of 1.172, and contained 123.8 grams of Na_2CO_3 and 49.3 grams of NaCl per litre.
- (44) **Rait Pario**, north of and close to Nau Rait, is also a comparatively new producer. It is about the same size and depth as Nau Rait. Owing to excessive water it did not yield in 1918. The water had a specific gravity of 1.037, and contained 8.8 grams of Na_2CO_3 and 28.7 grams of NaCl per litre. In 1912-13 this *dhand* is reported to have produced about 5,700 maunds, but in 1915-16 and 1916-17 nothing was obtained, as also in 1918. In its present state the *dhand* is too saline to yield *chaniho*.
- (45) **Bhaun**, a *dhand* mentioned in the old list of 1899, is 2 miles north of Rait Pario, and is now dry.
- (46) **Kot Korro** (Koro or Kot Imamgarh *dhand*). While all the *dhands* hitherto mentioned lie east of the Kot Jubo meridian, Kot Imamgarh *dhand* is about $\frac{1}{4}$ mile S. of Fort Imamgarh. This old fort is described by the Gazetteer as "the Gibraltar of the Khairpur Mirs," and lies 16 miles N.W. of Kot Jubo. It was visited by a military mission under Sir Charles Napier in 1843. The *dhand* is about 2 acres in extent with 2 feet of water. No *chaniho* was obtained in 1918 owing to excess of water.

The list of forty-six *dhands* given above completes the description of the *dhands* of the Kot Jubo area, which have ever been known to produce *chaniho*.

Commencing with the most southerly *dhand* of the large non-producing *dhands*, which have never concentrated sufficiently to deposit *chaniho*, the first is—

Large alkaline *dhands*
of Kot Jubo area.

- (1) **Narui**, a *dhand* nearly a mile in length with a depth of about six or seven feet, is marked on the map, but not named. It is the *dhand* east of Lai-wari (see No. 5 of previous list) i.e., the *dhand* east of that shown on the map as Guddanwaree. The water had a specific gravity of 1.057, and contained 31.9 grams of Na_2CO_3 , and 25.6 grams of NaCl per litre. The size and shape of the *dhand* can be seen from the map.
- (2) **Dabura**, shown on the map as Daboorah je Dhund, is 5 furlongs in length, hardly a furlong broad at its broadest part, and is about 7 or 8 feet deep. The water had a specific gravity of 1.059 and contained 34.7 grams of Na_2CO_3 and 30.3 grams of NaCl per litre.
- (3) **Savari Ulan** (or West *dhand*), marked on the map as Savaree je Dhund, is a narrow *dhand* about half a mile in length, and contains about 8 feet of water. The breadth is about 150 feet. The water had a specific gravity of 1.044, and contained 26.0 grams of Na_2CO_3 and 25.3 grams of NaCl per litre.
- (4) **Savari Ubrand** (or East *dhand*) is marked wrongly on the map as Turhan je Dhund. It lies close to but east of (3), and is roughly about the same size. Its water has not been tested.
- (5) **Turhan dhand**.—In my description of the Gapnum *dhand* I have noted the error in the map whereby the Savari Ubrand *dhand* is labelled Turhan, and the *dhand* known to the local people as Turhan is either unmarked or is wrongly placed. Turhan is about $\frac{3}{4}$ mile north of Savari Ulan and is a long narrow *dhand*, about 650 by 100 yards, with a depth of 8 or 9 feet. Its water had a specific gravity of 1.045, and contained 32.5 grams of Na_2CO_3 and 13.0 grams of NaCl per litre.
- (6) **Sanhri**, a small narrow *dhand* not quite 3 furlongs in length, lies S.E. of Sahai. It is marked on the map but not named. Its water was not tested.

- (7) **Sahai dhand**, marked on the map as Sahae je Dhund, is one of the largest of the Kot Jubo *dhands*. It has probably 10 feet of water but there is shallow water in the middle of the *dhand*. The *dhand* is slightly over a mile long and is $\frac{1}{4}$ mile broad. Sahai has a specific gravity of 1.038 and contains 15.1 grams of Na_2CO_3 and 25.7 grams of NaCl per litre. The lake was covered with thousands of flamingo (*Phoenicopterus roseus*) at the time of my visit. These birds, which were also abundant on Leyara *dhand* (see below) appear to prefer the saline to the alkaline *dhands*.
- (8) **Machoi** (or Mujoi *dhand*), marked on map, lies about a furlong north of Sahai, and is a long very narrow *dhand*. Its water had a specific gravity of only 1.009, containing 4.8 grams of Na_2CO_3 and 2.0 grams of NaCl per litre.
- (9) **Lun Khan Ubrand dhand**. In the 1860 map there are two *dhands* about $1\frac{1}{2}$ miles N.W. of Sahai: these are named Sone je Dhund and Noon Khan je dhand. These two *dhands* were united into one *dhand* at the time of my visit. Mr. Mahommed Khan, who lived for many years near Kot Jubo and is very familiar with the past history of this country, could not remember that there was ever more than one long *dhand*, which he called Lun Khan not Nun Khan. He observed also that there was another *dhand* known as Lun Khan about 7 miles to the west, and lying to the N.E. of Kinri *dhand*. It will be observed that there are two *dhands* marked on the map in this part, viz., Lanehwalee Tith and Dhoon Khan jo Doobhan. The name Laniwari is now applied to a *dhand* of small extent lying some 2 miles to the north of these *dhands* (see *ante*). It would appear that the *dhand* marked on the map as Lanehwalee is really Lun Khan Ulan *dhand*, since the latter *dhand* is described as a very long narrow *dhand* of over a mile in length: this description could only apply to Lanehwalee. The water of Lun Khan Ubrand has a specific gravity of 1.035 and contains 12.7 grams of Na_2CO_3 and 26.3 grams of NaCl per litre. The *dhand* as it was at the time of my visit was nearly a mile long but very narrow, and probably with not more than 4 or 5 feet of water.

- (10) **Leyara** is the northern of the two *dhands* marked Chundroee jo Dhund on the map. It is a *dhand* over $\frac{3}{4}$ mile in length, over a furlong broad at its northern end, and probably 6 to 7 feet deep. Leyara is a saline *dhand*, not alkaline. Its specific gravity is 1.075 and its water contains 90.4 grams of NaCl per litre, while the CO_2 present calculated as Na_2CO_3 is equivalent to 1.7 grams of Na_2CO_3 . The water of Leyara is clear and not yellowish or reddish as is that of the alkaline *dhands*.
- (11) **Chandroi** is marked on the map as a long *dhand* some $2\frac{1}{2}$ miles in length, i.e., the southern of the two *dhands* named Chundroee jo Dhund. In reality there are two *dhands* in this length of $2\frac{1}{2}$ miles shown in the map. Chandroi is $1\frac{1}{4}$ miles in length and is separated by a bar from the southern part at a point half a mile W.N.W. of Ramzan je Wand. The southern part, which runs into the Pur Chandar *dhand*, is called Dukani. The water of Chandroi has a specific gravity of 1.114 and contains 25.3 grams of Na_2CO_3 and 102.3 grams of NaCl per litre. It is thus a highly saline *dhand*, although more alkaline than Leyara.
- (12) **Dukani** is a long very narrow *dhand*, in places about 10 yards across, in length about $1\frac{1}{4}$ miles between Chandroi and Pur Chandar. It is separated from Chandroi by a bar of sand, but at the time of my visit it had a channel into Pur Chandar. In drier years it is separated from Pur Chandar by the drying up of this channel. Dukani though very narrow is probably 5 feet deep. Its water had a specific gravity of 1.069 and contained 47.9 grams of Na_2CO_3 and 27.8 grams of NaCl per litre.
- (13) **Pur Chandar dhand** is the deepest of all the *dhands* visited. I have already mentioned the local superstition that this lake was bottomless. I sent out a man on a raft to sound it in various places, but he touched bottom with a long pole easily. I do not think the *dhand* can be much over 15 feet in depth at its deepest. It is said to have diminished greatly in size of late years, especially at its south end. Quantities of sand are continually being blown into it. In spite of its depth, there is curiously

enough a small island in the middle. The size of the *dhand* can be judged from the map, but it is a little smaller than as shown. Its water has a specific gravity of 1.070 and contains 48.1 grams of Na_2CO_3 and 28.9 grams of Na_2Cl per litre.

(14) **Kinri** or **Kinriwari** *dhand* is 6 miles west of Chandroi and is marked on the map. Its water contains 50.2 grams of Na_2CO_3 and 14.0 grams of NaCl per litre, and has a specific gravity of 1.064.

(15) **Lun Khan Ulan**.—This *dhand* appears to be the same as that marked Lanehwalee Tith on the map (see note on Lun Khan Ubrand). Unfortunately the specimen of its water was broken in transit and could not be tested.

It is necessary to make the following corrections in the map.

Corrections in the
Survey of India Map
sheet 44 Sindh Revenue
Survey, scale 1"=1 mile.

The *dhand* marked Guddanwaree should be Laiwari. A *dhand* should be drawn in the *tali* immediately west of Laiwari and should be marked Gadanwari.

The *dhand* east of that wrongly named Guddanwaree should be marked Narui.

Savaree je Dhund should be Savari West, and the *dhand* marked Turhan je should be Savari East.

Turhan is a large *dhand* $\frac{3}{4}$ mile north of Savari West, and should be marked on the map, but is not.

The *dhands* Sone je and Noon Khan should be joined into one and marked Lun Khan the Eastern.

Padru *dhand* marked but not named on the map is drawn much too small.

The *dhand* marked Chundroee immediately south of Bhewalee should be named Leyara.

South of the Leyara *dhand* there is shown on the map a *dhand* of about $2\frac{1}{2}$ miles in length, which is named Chundroee jo Dbund. There are in reality two *dhands* here separated by a bar of sand at a point $\frac{1}{4}$ mile N.W. of Ramzan je Wand. The northern of these two *dhands* is the true Chandroi, and the southern Dukani.

The *dhand* marked on the map as Lanehwalee Tith situated about 5 miles W.N.W. of Chandroi appears to be known now as Lun Khan Ulan.

It is remarkable that in the more open country to the north of the *dra-ins* the proportion of salt to soda is very much greater than in those *dhands* which lie in the middle of the *dra-ins*. This can be seen from a comparison of the analyses of the water of Pur Chandar with that of Dukani, Chandroi, and Leyara. While Pur Chandar contains about 5 grams of carbonate for every 3 grams of chloride. Leyara is entirely a saline *dhand*, the two intervening *dhands* Dukan and Chandroi showing decreasing proportions of soda. An exception to this is the large Sahai *dhand*, which, although highly saline itself, is enclosed on the north and south by more alkaline *dhands*.

I conclude this chapter with one tabular statement showing the state of the *dhands* of the Kot Jubbo area as they were in 1918-19.

TABLE IV.—Table showing the state of the Khairpur *dhands*, Kot Jubo region, as they were in season 1918-19.

Producing.	Dry.	Excessive Water.	<i>Dhands</i> which never produced owing to excess of water.
Pakhyaro. Ganwarwaro. Nainwaro. Gadanwari. Laiwari. Pharanwaro. Kharowaro. Suji Wadi Suji Nandhi. Abdul Rahim.	Achro. Bambalui Nandhi. Rahimwaro. Gidharwaro. Jaranwaro. Padrio. Watwaro. Waranwaro. Matranwaro. Manchur. Jhandoi Nandhi. Sanoi Nandhi. Rojewaro. Letan Abdul Rahim. Bhaun.	Kalbuwaro. Gapnum. Ahirowaro. Padru. Bambalui Wadi. Kandiwaro. Boranwaro. Garho Got Kharro. Jhandoi Wadi. Gandhi. Dabho. Sanoi Wadi. Sanoi Kotenwari. Sanoi Garhi. Sanoi Narwari. Gabanwaro. Laniwari. Nau Rait. Rait Pario. Kot Korro.	Narui. Dabura. Savari Ulan. Savari Ubrand. Turhan. Sanhri. Sahai.* Machoi.* Lun Khan Ubrand. Leyara.* Chandroi.* Dukani. Pur Chandar. Kinri. Lun Khan Ulan.
10	15	21	15

Those *dhands* marked with asterisks are never likely to deposit irona owing to a deficiency of carbonate,

CHAPTER IV.

THE NAWABSHAH OR NASRAT TALUQA OF THE NAWABSHAH DISTRICT.

The *chaniho* deposits of the Nawabshah district lie on its north-eastern margin entirely within the limits of the Nawabshah or Nasrat taluqa. This district was formerly part of the Hyderabad district, from which it was separated about six years ago owing to the growth and excessive size of the latter.

The *dhands* which yield *chaniho* lie in the sand hills north of the Jamrao Canal, near the Jamrao Head. Owing to the embankment of the canal and the control of the flood water, this region has been gradually drying up, so that the number of producing *dhands* has become greatly circumscribed.

In the year 1903, this area was reported upon by the then Salt Inspector of the Naushehro division. A translation of his report, which was in Sindhi, was kindly given to me by Mr. Thurley. He gives a list of 18 *dhands*, with brief notes on each. I give below in brief the substance of the Inspector's report.

List of dhands in which chaniho or phuli¹ is produced in the Nawabshah Taluqa.

- (1) **Kelahu.**—Water brackish; no *chaniho* at present (June 1903), but is expected in July.
- (2) **Korki.**—Water brackish; 2 heaps (about 10 maunds) of *phuli* obtained.
- (3) **Leinwari.**—Dry; 4 heaps of *phuli*, no more obtainable in 1903.
- (4) **Lathwari.**—Dry; after rain *chaniho* and *phuli* both obtained; in all, 6 heaps of *chaniho* and 9 of *phuli*.
- (5) **Jaganwari.**—Dry; 11 heaps of *phuli* obtained; no more expected in 1903.
- (6) **Minwari.**—Water brackish; yielded 4 heaps of *chaniho* and 11 of *phuli*, weighing 24 and 40 maunds respectively. More may be obtained.

¹ The word *phuli* derived from *phul*, a flower, signifies efflorescent salt.

- (7) **Patehu**.—Water brackish, some *phuli*; may deposit *chaniho*.
- (8) **Paniwari**.—Water brackish; no prospects of *chaniho*.
- (9) **Khabbarwaro**.—Water brackish; at present only yields *phuli*. There are hopes of a further yield.
- (10) **Phogwari**.—Water brackish; no prospect of *chaniho*.
- (11) **Gulabwari**.—Dry; owing to rain 10 heaps (about 60 maunds) of *chaniho* were produced, but no *phuli*.
- (12) **Ridhwari**.—Water brackish; at present no prospects of either *chaniho* or *phuli*.
- (13) **Sari No. I**.—Dry. About 32 maunds of *phuli* obtained.
- (14) **Sari No. II**.—Owing to rain water, both *chaniho* and *phuli* were obtained; 6 heaps or 20 maunds of the former, and 20 heaps or 100 maunds of the latter.
- (15) **Khororo**.—Water brackish; 12 maunds of *chaniho* obtained.
- (16) **Dinganwaro** or **Deganwaro**.—Owing to rain water, this *dhand* yielded 6 heaps (30 maunds) of *chaniho* and some *phuli*.
- (17) **Bolahi**.—Water brackish; only *phuli* obtained, 20 heaps amounting to about 100 maunds.
- (18) **Akanwari**.—Water brackish, and no prospects of *chaniho* at present, but this *dhand* may produce in the future.

In addition to the above list of 18 *dhands*, the Mukhtyarkar of Nawabshah furnished me with the names of other *dhands* in this area not included in the list of 1903. Some of these have never produced *chaniho*, but their waters are brackish (*khara*).

- (19) **Sanhri**, containing excessive water in 1918.
- (20) **Chugeri**, dry in 1918.
- (21) **Wasuwari**, dry in 1918.
- (22) **Manakwari**, containing excessive water in 1918.
- (23) **Soro**, dry in 1918.
- (24) **Gunjo**, dry in 1918.
- (25) **Kilanwari**, dry in 1918.
- (26) **Gidharwari**, dry in 1918.
- (27) **Gundwari**, dry in 1918.

These lists came into my hands after the conclusion of my visit to the Nawabshah taluqa. I was shown only three producing *dhands* in December 1918, viz., Akanwari, Kilanwari, and Phogwari, and was informed that these were the only *dhands* which had pro-

duced that year. This information appears to be quite correct since it corresponds with that given me by the Mukhtyarkar of Nawabshah. I examined all the producing *dhands*, but only a few of those which were dried up, since little or no information can be obtained by visiting a dried up *dhand*.

Taking the *dhands* in the order listed above, I shall now describe their positions with brief notes :—

- (1) **Kelahu** is shown on the map as Gelahoo, and lies $3\frac{1}{4}$ miles west of Jamrao (Jamrahoo) village. It was a small perfectly dry depression with *kalar*, of about an acre in extent, and had produced no *chaniho*, but the mineral is said to be obtained in the rains.
- (2) **Korki** is $1\frac{1}{4}$ miles N.N.E. of (1) and is a similar dry depression, but larger than Kelahu. Only *kalar* visible, no *chaniho*.
- (3) **Lainwari**.—The Mukhtyarkar reports that no *dhand* of this name is known, and thinks that the *dhand* Lathwari is alluded to, which he suggests that the Inspector of Salt duplicated in error in his list in 1903.
- (4) **Lathwari**.—This *dhand* is half a mile S.W. of Korki and is reported to be perfectly dry with only *kalar* appearing. It is about three acres in extent.
- (5) **Jaganwari** appears to be identical with Jooga Khanoo of the map of 1860. It is a little smaller than Lathwari, and was quite dry with only *kalar* visible.
- (6) **Minwari** is also quite dry with only *kalar* visible. It lies close to and S.W. of Jaganwari, and is about the same size as Lathwari.
- (7) **Patahu** is marked on the map as Putahoowaree, and was dry with only *kalar* visible. It is about the same size as Minwari.
- (8) **Paniwari** is N.W. of and close to Patahu. It was dry with only *kalar* visible.
- (9) **Khabarwari**.—East of Paniwari and about one furlong distant. Completely dry with only *kalar* visible.
- (10) **Phogwari**.— $\frac{1}{4}$ mile N.W. of Goonja jo Sim. When I saw Phogwari in December 1918, there was a small pool in the middle of the *dhand* about 10 feet in diameter, with a scum of *chaniho* on the top of the water. The rest of the *dhand* was covered with *kalar*.

- (11) **Gulabwari** is $\frac{1}{2}$ mile N.E. of Phogwari and S.W. of Goondawaree (see map). It was reported to be dry, but to have yielded *chaniho* and *phuli* recently.
- (12) **Ridhwari** is $\frac{1}{2}$ mile N. of Phogwari. It was dry, with only *kalar* visible, but is reported to have yielded *chaniho* in recent years.
- (13) **Sari No. I.**—This is N.W. of Patahu, and may be identical with the Suhaoowaree of the map. It was dry, with only *kalar* present.
- (14) **Sari II** is west of, and close to, Sari I. It was also dry with only *kalar* visible.
- (15) **Khororo.**—This *dhand* is marked on the map as Dhund Khororee. It is $\frac{1}{2}$ mile S.W. of Bolahi (Sim Bolaewaro of map). It is reported to be about 5 acres in extent, with 3 feet of water. It yielded no *chaniho* within the last two years. A sample of the water, on analysis, was found to have a specific gravity of 1.068, and to contain 42 grams of Na_2CO_3 , 24 grams of Na_2SO_4 , and nearly 6 grams of NaCl.
- (16) **Dinganwaro** is $\frac{1}{2}$ mile S.E. of Kurunda Wado *dhand* (marked Simm Wuddee Jorindawaree of the map). Dinganwaro was dry with only *kalar* visible, but like others of these Nawabshah *dhands*, it was said to yield *chaniho* in the rainy season.
- (17) **Bolahi** (marked Simm Bolaewaro on the map) is reported to be 15 acres in extent, with a depth of from 2 to 4 feet of water. It yielded no *chaniho* within the last two years. The water of Bolahi is very similar to that of Khororoh, with a sp. gr. of 1.069 and containing 43 grams of Na_2CO_3 , nearly 26 grams of Na_2SO_4 , and $6\frac{1}{2}$ grams of NaCl per litre.
- (18) **Akanwari.**—This *dhand* is the only really important producer of the Nawabshah *dhands*. It appears to be identical with the *dhand* marked Sathedwaree Simm on the map of 1860. It is a *dhand* of oval shape, but narrow, being about 200 by 50 yards, with 2 feet of water. There were 114 stacks of *chaniho*, each of about 4 to 5 maunds. The *chaniho* appeared to be of a good quality, of a fairly white colour, and comparatively free from organic matter. The water of Akanwari had a

specific gravity of 1.110, and contained 79.5 grams of Na_2CO_3 , 73.5 grams of NaHCO_3 , 37.5 grams of NaCl , and a trace of Na_2SO_4 , per litre. An analysis of the *chaniho*, which appears to be fairly pure, is given in Chapter VI.

- (19) **Sanhri** (near the Sunhuree Bhit of the 1860 map) is reported to be $1\frac{1}{2}$ acres in extent, and to have a depth of 1 foot. The water had a sp. gr. of 1.049, and contained 14.9 grams of Na_2CO_3 , 28.2 grams of NaCl , and 14.6 grams of Na_2SO_4 per litre.
- (20) **Chugheri**, a small dry *dhand*, $\frac{1}{2}$ miles south of Wasuwari, which see. No yield in 1918.
- (21) **Wasuwari**, also dry, is east of Wasoowaree Bhit as marked in the map.
- (22) **Manakwari** is about half a mile S.E. of Bolahi and south of Akanwari. It covers about 2 acres and has a depth of about 3 feet. It is slightly brackish having a sp. gr. of 1.016, and containing 7.5 grams of Na_2CO_3 , 4.7 grams of NaCl , and 3.6 grams of Na_2SO_4 per litre. No *chaniho* has been obtained within the last two years.
- (23) **Soro**, dry, lies south of and close to Jaganwari (see *ante*).
- (24) **Gunjo**, dry, lies S.E. of and close to Jaganwari.
- (25) **Kilanwari**, identical with Guree Sim of the map, and east of Jaganwari, was dry with only one small heap of *chaniho* and some *kalar* visible, but *chaniho* is said to be obtained in the rains.
- (26) **Gidharwari** is half way between Kilanwari and Phogwari, and is close to Goonja jo Sim. It was dry.
- (27) **Gundwari**, N.E. of Phogwari and Gulabwari, is near the Goondawaree Bhit of the 1860 map. It was dry.

The Kurunda *dhands*, viz., **Kurunda Wado**, marked on the map as Wuddo Jorindawaree, and **Kurunda Nandho**, marked Jorindawaree Simm, are fresh water. The CO_2 estimated as Na_2CO_3 amounts to only 1.2 grams per litre, while the NaCl present is less than 0.5 grams. The water of **Gunja**, marked Goonja jo Simm is also fresh. The desiccation and gradual deterioration of the Nasrat taluqa deposits is apparent when we compare the state of the *dhands* in 1903, shortly after the opening the Jamrao Canal with their state in 1918.

TABLE V.—Table showing the state of the Nasrat dhands in 1903 and in 1918

Name of <i>dhand</i> .	State in 1903.	State in 1918.
Kelahu.	Excessive water.	Dry ; produces in rains.
Korki.	Excessive water.	Dry.
Lainwari.	Dry ; producing in rains.	Not known.
Lathwari	Dry ; producing in rains.	Dry.
Jaganwari	Dry.	
Minwari.	Water ; producing.	Dry.
Patahu.	Excessive water.	Dry.
Paniwari.	Excessive water.	Dry
Khabarwaro.	Excessive water.	Dry.
Phogwari	Excessive water.	Almost dry ; producing.
Gulabwari.	Dry ; producing in rains.	Dry .
Ridhwari	Excessive water.	Dry.
Sari I.	Dry, yielding efflorescent salt (<i>phuli</i>).	Dry.
Sari II.	Dry ; producing in rains.	Dry.
Khororo.	Water ; producing.	Excessive water.
Bolahi.	Excessive water ; yielding <i>phuli</i> only.	Excessive water.
Akanwari.	Excessive water.	Producing plentifully.
Dinganwaro	Dry ; producing in rains.	Dry ; producing in rains.

It is curious that Khororo should appear as a producing *dhand* in 1903, but as having excessive water in 1918, contrary to the general tendency. It is possible that *chaniho* may have been collected from pools at its margins in former times, but there is no information on this point. The majority of the other *dhands* clearly show how great has been the desiccation of this area, owing to the embankment of the Jamrao Canal.

TABLE VI.—Table showing the state of the Nasrat dhands in 1916.

Producing.	Dry.	Excessive water, and brackish dhands which never produced.
Phogwari.	Kelahu.	Khororo.
Akanwari.	Korki.	Bolahi.
Kilanwari.	Lainwari.	Sanhri.
	Lathwari.	Manakwari.
	Jaganwari.	
	Minwari.	
	Patahu.	
	Paniwari.	
	Khabarwaro.	
	Gulabwari.	
	Ridhwari.	
	Sari I.	
	Sari II.	
	Dinganwaro.	
	Ohugheri.	
	Wasuwari.	
	Soro.	
	Gunjo.	
	Gidherwari.	
	Gundwari.	
TOTALS 3	20	4

From the above table, it will be seen that there is little hope of expanding the *chaniho* production of Nasrat. Of the three producing dhands, Kilanwari and Phogwari were practically dry with a very small production. Akanwari is the only good producing dhand. It is true that some of the dry dhands produce after rain, but this

is both entirely dependent on the rainfall, and results in only small yields of impure *chaniho* of very low grade. Of the four brackish *dhands*, Kororo and Bolahi might produce in future, but Sanhri is too saline to yield good *chaniho*, while Manakwari has a very low percentage of dissolved salts, and is not likely to become sufficiently concentrated in the near future. The only *dhands* which afford any hope of expanding the industry are then Khorero and Bolahi.

CHAPTER V.

THE THAR AND PARKAR DISTRICT ; SANGHAR AND KHIPRO TALUQAS ; DIPLO AND MITHI TALUQAS ; AND KARACHI DISTRICT.

The working the deposits of *chaniho* in the Thar and Parkar district was stopped by order of the Commissioner in Sind in the year 1902 (letter No. C-277, dated April 23rd, 1902, to the Deputy Commissioner of Thar and Parkar).

All the *dhands* then worked for *chaniho* proved to be dry in January 1919.

It was necessary therefore to make a complete survey of all the *dhands* of these taluqas in order to ascertain whether any new *dhands* which might have contained excessive water in 1902 had become sufficiently concentrated to deposit *chaniho*.

Before proceeding to describe the *dhands* of these taluqas, I will briefly relate the circumstances which led to the closing of the industry in Thar and Parkar.

Thar and Parkar had for many years produced *chaniho*. The industry is mentioned in the first edition of the Sind Gazetteer published in 1874. Pottinger¹, writing in 1816, states that alkali was one of the main exports from Karachi, and it may be assumed that this alkali came from Thar and Parkar, Nawabshah, and Khairpur.

The output of Thar and Parkar from 1893 to 1899 was as follows : ²—

TABLE VII.—*Output of chaniho and phuli from 1893 to 1899 in Thar and Parkar.*

—				<i>Kharo chaniho.</i>	<i>Phuli.</i>	TOTALS.
				maunds.	maunds.	maunds.
1893-94	.	.	.	3,153	.....	.....
1896-97	.	.	.	3,441	4,133	7,574
1897-98	.	.	.	2,800	3,200	6,000
1898-99	.	.	.	800	2,700	3,500

¹ Pottinger, Lieut. H., "*Travels in Beloochistan and Sindh*", p. 244.

² Letter of Commr. in Sind, No. C-75 of 1901.

and it was considered that in an average year about 4,000 maunds were collected. Since 1877 the collecting of *chaniho* from the Sanghar and Khipro *dhands* was farmed out, and an auction was held every year for the right to extract *chaniho* over the period of one year from August to July. The prices realised for this right were as follows :—

Year	Rs.
1894-95	1,925
1895-96	1,925
1896-97	7,000
1897-98	4,050
1898-99	2,700

In January 1899 the Chief Collector of Customs in Karachi ordered the Special Salt Inspector in Sind to tour the Thar and Parkar district and to report on the state of the salt deposits, etc., there.

On the 30th March 1899, the Special Salt Inspector reported that some of the *kharo*¹ and *phuli* (efflorescence) removed from the *dhands* could be used as common salt, and he requested that the deposits of the chief *chaniho* producing *dhand* of Thar and Parkar, — a *dhand* named Dabhiwari in the Khipro taluqa—might be tested, whereupon the high percentage of chloride would become apparent.

He explains in a subsequent letter that *kharo* and *chaniho* are synonymous terms both indicating a hard crystalline deposit from a concentrated bittern, while the term *phuli* denotes a soft powdery efflorescence.

Three samples of *chaniho* and *phuli* were now sent to the Chemical Examiner in Bombay. These samples presumably came from Dabhiwari. On analysis they were announced to contain 84 per cent., 53 per cent., and 43 per cent. of NaCl. respectively, the remainder being CO₂ and SO₄ with bases Na, K, and Mg.

As soon as it became apparent that the excise duty on salt was likely to be evaded by the traders in this very impure *chaniho* who sold an article purporting to be soda, but in reality largely salt, the matter was energetically taken up by the Salt Department. The *chaniho* sold in Karachi bazaar was now analysed, but the two specimens sent to the Chemical Analyst showed only 5 and 3 per cent. of NaCl respectively. Probably these specimens were from Khairpur.

¹ The terms *kharo* and *chaniho* are synonymous, both signifying trona.

Meanwhile the Deputy Commissioner of Thar and Parkar forbade the removal of the heaps of *chaniho* at Dabhiwari, of which there were estimated to be 3,200 maunds. I saw the remains of these heaps in 1918, and collected a specimen of the *chaniho* for analysis, see Chapter VI.

The following *dhands* were being worked at this period:—

(1) Dangi jo Chaho	Sanghar taluqa.
(2) Sahib Dinai jo Puso	" "
(3) Kariwari	" "
(4) Bodlo	" "
(5) Sanhri	Khipro taluqa.
(6) Mitho Puso	" "
(7) Laiwari	" "
(8) Garho Puso	" "
(9) Laniwari	" "
(10) Dimunwari	" "
(11) Dabhiwari	" "

and there were at least nine other places, the names of which are not recorded, from which *chaniho* was produced. The *dhands* are given above in geographical order from N.W. to S.E.

A Committee was then appointed consisting of the Mukhtyarkars of Sanghar and Khipro, the Special Salt Inspector, and the Deputy Collector of the E. Nara Valley, who were sent to examine and report upon the *chaniho* industry in these taluqas.

The Committee collected the following samples, which were afterwards analysed:—

Dabhiwari, from the *chaniho* stacks of 1896-97, four samples with 85 per cent., 64 per cent., 73 per cent. and 25 per cent., of NaCl respectively.

Dabhiwari, from the *chaniho* stacks of 1898-99, three samples with 70 per cent., 43 per cent. and 30 per cent., of NaCl respectively.

Laiwari, sample of *phuli* containing 20 per cent. of NaCl.

Laiwari, two samples of *chaniho* containing 58 per cent. and 89 per cent. of NaCl respectively.

Bodlo, sample of *phuli* containing 22 per cent. of NaCl.

Garho Puso, sample of *phuli* containing 7 per cent. of NaCl.

Mitho Puso, sample of *chaniho* containing 8 per cent. of NaCl.

Sanhri, sample of *phuli* (?) containing 19 per cent. of NaCl.

Kariwari, sample of *phuli* containing 24 per cent. of NaCl.

Sahib Dinai jo Chaho, sample of *phuli* containing 34 per cent. of NaCl.

Dangi jo Chaho, sample of *phuli* containing 35 per cent. of NaCl.

The Deputy Collector of the East Nara, in forwarding the Committee's report, states that *chaniho* is not annually found in the same set of *dhands*. "After a few years" he says "the conditions change, and no *chaniho* is found there, but is found in other places where there was none for years." He proceeds to point out that in the same *dhand* are found several grades of *chaniho*, a superior quality used as baking powder for pulse-cakes, and an inferior salty quality used for washing and dyeing. Re. 1-8-0 is obtained per maund for the superior, and As. 10 per maund for the inferior quality. Most of the *chaniho* is collected in May or June, *i.e.*, when the *dhands* have been evaporated to their greatest concentration.

During the enquiry into the *chaniho* industry, the Salt Department collected and analysed 41 samples of *chaniho* and *phuli* from the *dhands* of Khairpur State. I have given a list of 37 of these *dhands* and the results of the analysis in Chapter III, p. 232.

Comparing the results of the analysis of the Khairpur *dhands* with those of Thar and Parkar, it will be seen that while the majority of the Khairpur *dhands* yielded a fairly pure *chaniho*, those of Thar and Parkar had in many cases over 50 per cent. of NaCl. Apparently the deterioration of the Thar and Parkar *chaniho* was in 1899 only a recent feature. Mr. W. H. Lucas, then Deputy Commissioner of Thar and Parkar, in a letter to the Commissioner in Sind¹ states that he had questioned a man who had been employed for 25 years in removing *chaniho* from the deposits of the district, and that this man stated that it was only since 1896-97, that this very highly salt impregnated kind had been deposited.

Mr. Lucas describes in his letter the conclusions he arrived at after having visited the Dabhiwari *dhand*. He emphasises the fact that many different grades of *chaniho* are hopelessly mixed together in the produce of one *dhand* in one year. "*Chaniho* highly impregnated with salt might lie," he says "side by side in the bed of the *dhand* with *chaniho* which contained hardly any salt. The same *dhand* often produces quite pure *chaniho* one year, and very

¹ Letter to the Commr. in Sind, No. 681, dated 5th April 1900.

salt *chaniho* the next." The observations of Mr. Lucas are of course perfectly clearly explicable to anyone who understands the principles governing the deposition of trona from carbonate-chloride and carbonate chloride-sulphate waters. The various deposits of the Lonar Lake in Berar illustrated this.¹

As a result of this enquiry into the *chaniho* industry of Thar and Parkar, the Government of Bombay, who had previously ruled that all alkali produced in Bombay Presidency, excepting the Province of Sind which contained more than 50 per cent. of NaCl should be dutiable as salt, extended their orders to Sind on the 19th April 1902.² Acting on these orders, the Commissioner in Sind ordered the closing of the *chaniho* deposits of Thar and Parkar;³ this order, which was passed on the 23rd April 1902 ended the Thar and Parkar industry.

At the time of my visit, the industry was quite forgotten, and I could get no local information. The name Mitho Puso,—a well known *dhand* in 1899—could not be identified with any locality in Khipro or Sanghar. Enquiries made by the Mukhtyarkars failed to solve the question: the local inhabitants appeared to have few memories of the industry, and many of the older amongst them had been carried away by the influenza epidemic. I found that in general very few of the names on the map of 1860 were remembered. With the aid of Mr. Thurley and his subordinates, I was able to test samples of water from nearly every *dhand* in Sanghar and Khipro, and in this way I was enabled to form a clear idea of the distribution of alkaline waters in these taluqas. I shall commence my description with the northern part of Sanghar.

The most northern *tapa*⁴ of Sanghar is the Jakrao *tapa*, which was formerly part of the territories of the Sanghar taluqa. Khairpur State, but was ceded to British administration at the time of the construction of the Jamrao Canal. The *tapa* lies to the S.E. of the Nasrat taluqa of Nawabshah, but there are no *dhands* of a salt or alkaline type west of the Nara.

¹ See *Rec. Geol. Sur. Ind.*, XLI., p. 266.

² No. 2623, Revenue Department of Government of Bombay, dated April 19th, 1902.

³ No. C-277, Commissioner in Sind, dated April 23rd, 1902.

⁴ In Sind a *taluga* is subdivided into three or four *tapas* under *tapadars*, for collection of revenue.

The following *dhands* east of the Nara were reported to be sweet water :—

Lukunwaro, $9\frac{1}{2}$ miles S.E. of Jamrao Head, and 6 miles N.E. of Jakrao.

Punwaro, $\frac{1}{2}$ mile east of Lukunwaro.

Jhandewari, $1\frac{1}{2}$ miles south of Lukunwaro.

Satnewari, $\frac{1}{2}$ mile east of Jhandewari.

Pirwari, 2 miles E.S.E. of Jhandewari.

Bajriwari, 3 miles S.E. of Pirwari, and 1 mile north of Badarwaro Kot.

Laihoru, 1 mile S.E. of Badarwaro Kot, and west of Sumana.

Marrowari, $1\frac{3}{4}$ miles N.E. of Badarwaro Kot.

Bahunwari, $1\frac{1}{2}$ miles east of Sumana.

Gari, $\frac{3}{4}$ mile south of Sumana.

Specimens of the water of four *dhands*, supposed to be slightly brackish were brought to me by the Supervising Tapadar.

Badarwari, $\frac{1}{4}$ mile N.E. of Badarwaro Kot. The water of this *dhand* had a sp. gr. of 1.000, and contained CO_2 corresponding to less than half a gram of Na_2CO_3 per litre.

Gidderunwari, $\frac{1}{2}$ mile south of Badarwari. The water of this *dhand* had a specific gravity of 1.004 and contained CO_2 corresponding to 1.6 grams of Na_2CO_3 per litre.

Kalachwari, $\frac{1}{4}$ mile south of Gidderunwari. The water of this *dhand* had a specific gravity of 1.011, containing 1.5 grams of Na_2CO_3 and 8 grams of NaCl per litre.

Gati Vagi, 1 mile south of Kalachwari. The water of this *dhand* had a specific gravity of 1.000, and the equivalent of 0.5 gram of Na_2CO_3 .

Sanghar taluqa : In the Bakar *tapa* of Sanghar, the following
Bakar *tapa*. *dhands* east of the Nara occur. The order is geographical from N.W. to S.E. :—

Sirunwari, 5 miles S.E. of Sumana in Jakrao *tapa*. The water of Sirunwari has a sp. gr. of 1.039, but is saline with 40.4 grams of NaCl per litre, and less than 0.5 gram of Na_2CO_3 .

Bholuwari, $\frac{1}{4}$ mile S.E. of Sirunwari, has a sp. gr. of 1.020, containing 12.9 grams of NaCl and less than half a gram of Na_2CO_3 .

Ratrao (Ratrahoo), 1 mile N.E. of Bholuwari, is reported to be sweet water.

Kinri, $3\frac{1}{2}$ miles S.E. of Bholuwari, is dry.

Kari, $1\frac{1}{2}$ mile N.E. of Kinri, is dry.

Mahmuda, $\frac{1}{4}$ mile east of Kari, is dry.

Sukiawari, 3 miles S.E. of Mahmuda (Sookia of map), is reported to be a shallow *dhand*, 200 by 25 yards and 6 inches deep. The water had a sp. gr. of 1.021, and contained 10.2 grams of NaCl, 6.2 grams of Na_2CO_3 , and 5.8 grams of Na_2SO_4 per litre.

Rehro *dhand*, 2 miles S.W. of Sukiawari, and 5 miles N.N.E. of Bakar, is reported to be sweet water.

Nirawal *dhand* is a very small *dhand* immediately south of Dogacha and 1 mile S.E. of Rehro. The water had a specific gravity of 1.059, and* contained 20.4 grams of Na_2CO_3 , 21.8 grams of NaCl, and 24.6 grams of Na_2SO_4 per litre. There was very little water in the *dhand*.

Bahanwari is 1 mile E.S.E. of Dogacha and Nirawal. It is also a small *dhand*. The water had a sp. gr. of 1.054, and contained 20.9 grams of Na_2CO_3 , 24.6 grams of NaCl, and 15.5 grams of Na_2SO_4 .

Gari *dhand*, 1 mile south of Dogacha, is a small oval *dhand* covered with soft mud, on which there was a crust of impure *chaniho*. I attempted to get some water from the middle of the *dhand* where there was a large pool, 15 yards in diameter, but found it impossible to walk on the mud, which was deep and treacherous. A sample of water was taken from one of the smaller pools near the margin. This water had a sp. gr. of 1.154, and contained 57.2 grams of Na_2CO_3 , 71.7 grams of NaCl, and 70.7 grams of Na_2SO_4 .

Suru (Soor je) *dhand*, 1 mile south of Gari, and 3 miles N.N.E. of Bakar, is sweet water.

Bari *dhand*, 1 mile south of Suru, is sweet water.

Kharor je *dhand*, $2\frac{1}{2}$ * miles east of Suru (Soor je), has a sp. gr. of 1.042, but is saline, with less than 0.5 gram of Na_2CO_3 per litre.

Biyowi (Beoeje), 1 mile east of Kharor, is dry:

Panyal, 2 miles S.S.W. of Kharor and $3\frac{1}{2}$ miles east of Bakar, is a saline *dhand* with a sp. gr. of 1.034, containing 36.3 grams of NaCl, but less than half a gram of Na_2CO_3 per litre.

Ugam je *dhand*, 2 miles E.N.E. of Biyowi *dhand* (see above), is a good sized *dhand* with abundant reeds and vegetation. The water had a sp. gr. of 1.009, and contained 3.5 grams of Na_2CO_3 , and 5.3 grams of NaCl per litre.

Sanghar taluqa,
south-eastern portion.

Khari *dhand*, 1 mile east of Ugam, is a long narrow *dhand* about 250 by 80 yards, with about 2 feet of water. The water had a specific gravity of 1.048, and contained 25.9 grams of Na_2CO_3 , and 18.5 grams of NaCl per litre. It might be possible to obtain *chaniho* from this *dhand* at some future time.

Turunwari, west of Khari, is dry.

Sangriam je *dhand*, 3 miles S.W. of Ugam and 5 miles east of Bakar, is dry.

Rojuli *dhand*, which has been marked on the 1860 map as Kojdee, evidently through a mistake in reading the handwritten name, is dry. Rojuli is $\frac{1}{2}$ mile S.E. of Sangriam je.

Rarr *dhand*, $\frac{1}{2}$ mile east of Rojuli, is a very long *dhand* of sweet water, and full of crocodile.

Dangi jo Chaho is situated $\frac{1}{4}$ mile east of the north end of Rarr. It is the *dhand* marked but not named on the 1860 map, $\frac{1}{4}$ mile due west of the spot named Pudr Hamid Shah. Dangi jo Chaho was a *dhand* of soft treacherous mud with no water, but with abundant efflorescence. This *dhand* was worked in 1899 and preceding years for *chaniho*.

Sahib Dinai jo Chaho, also worked in 1899 and preceding years for *chaniho*, lies not quite half a mile south of Dangi jo Chaho, close to the trigonometrical station marked Rarr jee R. S. on the 1860 map. It is now a completely dry oval *dhand* covered with *kalar* efflorescence.

Dimunwaro Khuror or **Khuror** *dhand*, $1\frac{1}{2}$ miles S.E. of Rarr *dhand*, has water which, however, contains less than 0.25 grams of Na_2CO_3 per litre.

Lanari (Laneree jee) is dry. This *dhand* is 4 miles N.E. of Tando Mitha Khan, and 2 miles south of Dimunwaro Khuror.

Nahur dhand, 1 mile east of Lanari, is dry.

Banahu or **Bambahu**, N.E. of Nahur, is also dry.

Patehal (Putehul) *dhand*, $\frac{1}{2}$ mile S.E. of Nahur, has water, although much shrunk from its former size. The water had a sp. gr. of 1.06 but contained less than 0.25 grams of Na_2CO_3 per litre.

One mile east of Banahu, the large *dhand* marked as **Purai** (Poorae jee) has shrunk, so that the western portion is dry, while the eastern part is now two small *dhands* separated by dry land. That to the north is called **Purai dhand**, and that to the south is **Bakhvoro**.

Purai dhand is now about 250 by 80 yards, and has a specific gravity of 1.039 but contains less than 0.25 grams of Na_2CO_3 per litre. **Bakhvoro dhand**, which is a little larger than Purai, has a sp. gr. of 1.040 and contains about 0.75 grams of Na_2CO_3 per litre.

Bodlo (Bodulwaree), $\frac{1}{2}$ mile N.E. of Purai village, is dry. This is one of the old *dhands* worked before 1899 for *chaniho*.

South of Bakhvoro, and about 1 mile distant there is a long narrow *dhand* of sweet water.

Kari Vari is a name of one of the Sanghar *dhands* worked before 1899 for *chaniho*. No one could identify this name with any locality; the name Khari is a very common one, and there are several *dhands* so named, but which of these is meant in the old list cannot be now ascertained.

Patehal, Purai, and Bakhvoro are all saline *dhands*.

Toriwari dhand, on the boundary of Sanghar and Khipro, is dry. It is 8 miles N.E. of Tando Mitha Khan.

Sanhri dhand, 1 mile east of Toriwari, and $1\frac{1}{4}$ miles N.N.W. of Khumbro village is dry. This is one of the *dhands* worked previously to 1899.

Kari dhand, 1 mile west of Khumbro, contains water of a sp. gr. of 1.01, and with 4.6 grams of Na_2CO_3 per litre.

Mitho Puso, one of the old *dhands* worked previously to 1899, is probably identical with Mitha Poosa marked on the 1860 map as being $1\frac{1}{4}$ miles east of Khumbro. If the identification is correct, Mitho Puso is now dry.

Kharuki dhand, marked on the map as a very large *dhand* 6 miles S. by E. of Khumbro, although very greatly

diminished, contains water of a sp. gr. of 1.146, which is saline, with only 1.7 grams of Na_2CO_3 per litre.

Jakrao (Jukrahoo) *dhand*, formerly a very large *dhand*, now contains a little water in the deepest part. It has a sp. gr. of 1.014 with 3.4 grams of Na_2CO_3 per litre.

Munpur, about $1\frac{1}{2}$ miles N. of Jakrao, also contains a little water of a sp. gr. of 1.048, but saline with less than 0.8 gram of Na_2CO_3 per litre.

Budahu dhand, 1 mile N.E. of Munchur and 7 miles N. by E. of Khipro, also contains a little water of a sp. gr. of 1.048, but saline with less than 0.89 gram of Na_2CO_3 per litre.

Kundhi Tul dhand, $\frac{1}{2}$ mile east of Budahu, has a little water of a sp. gr. of 1.008 with 2.4 grams of Na_2CO_3 per litre,

Gapni (Gupnee), 3 miles N.N.E. of Budahu, is dry.

Laiwari, 1 mile N.E. of Gapni, is one of the old *dhands* worked before 1899, but is dry with only *kalar* visible.

Dimunwari (Dimunwaree Khuror) is another dry *dhand* with *kalar*, formerly worked for *chaniho*, situated 1 mile east of Gapni and S.E. of Laiwari.

Garho Puso, also worked previously to 1899, is now dry with only *kalar* visible.

Laniwari, 1 mile S. by W. of Rukhbm jo Tuss, and 1 mile east of Kundi Tul, is also dry, with patches of *kalar*. This is one of the old *dhands* worked previously to 1899.

Baharo (Buhareh), $2\frac{3}{4}$ miles east of Kundi Tul, contains saline water of a sp. gr. of 1.038, and with less than 0.4 gram of Na_2CO_3 per litre.

Dabhiwari is 3 miles south of Baharo. This *dhand* was the greatest producer of all the Thar and Parkar *dhands* previously to 1899. This *dhand* was dry, when I saw it early in January 1919, but owing to heavy rain at Christmas, there had been a little water in a small depression about 5 yards across in the centre of the *dhand*, which had dried up a day or two before my visit. In this depression I found a crop of crystals of mirabilite ($\text{Na}_2\text{SO}_4 \cdot 10 \text{H}_2\text{O}$) lying on the mud. Most of the crystals had dried to an opaque powdery condition, owing to their alteration to anhydrous sulphate (Na_2SO_4). On the shores of the *dhand* the old heaps of *chaniho* condemned in 1899 were still lying in a dilapidated condition.

Gug, 2 miles east of Dabhiwari, has saline water of a sp. gr. of 1.042 with less than 0.25 grams of Na_2CO_3 per litre. South of Gug are the following dry *dhands*, **Lalur**, **Gurkno**, **Bandki**, and **Chidki**.

Khariwari, supposed to be identical with Nurunwaree of the 1860 map, is saline with a sp. gr. of 1.027 and with less than 0.5 grams of Na_2CO_3 per litre. It is 3 miles S.E. of Dabhiwari.

Chaura Thur, $\frac{1}{2}$ mile east of Khariwari, is saline with a sp. gr. of 1.025 and with less than 0.4 grams of Na_2CO_3 per litre.

The *dhands* of the south-eastern part of Khipro are entirely saline. Dilyar (Dhiliar) is the headquarters of the Dilyar Salt Depot and Works. A *dhand* named Darwari, $5\frac{1}{2}$ miles E. by N. of Dilyar, is worked for salt by the Salt Department. The following is a list of the *dhands* in the south-eastern part of the Khipro taluqa (Dilyar is about 8 miles S.E. of Khipro, and the *dhands* mentioned are at varying distances up to 7 miles to the N.E., E., and S.E. of Dilyar).—

Khipro taluqa, south-eastern region.

Kinri, 4 miles S.E. of Dilyar, sp. gr. 1.007.

Bangrio, 5 miles S.E. of Dilyar, sp. gr. 1.012.

Manikpur, 6 miles S.E. of Dilyar, sp. gr. 1.091.

Shihunwari, 5 miles E.S.E. of Dilyar, sp. gr. 1.206. Abundant *chiroli*,¹ mounds round its shores.

Aantio, N.W. of and close to Shihunwari, sp. gr. 1.120.

Gaganwari, 5 miles E. by N. of Dilyar, sp. gr. 1.041.

Sumerat, 1 mile east of Gaganwari, sp. gr. 1.137 *Chiroli*¹ abundant.

Uthanwari, 1 mile S.W. of Gaganwari, sp. gr. 1.157.

Mural, 3 miles E. of Dilyar, sp. gr. 1.05. *Chiroli* abundant.

Sanhri, 4 miles N.E. of Dilyar, sp. gr. 1.127, *Chiroli* abundant.

Paniwari, $1\frac{1}{2}$ miles N. of Mural, sp. gr. 1.206. *Chiroli* abundant.

Kalarwari, 2 miles N.E. of Dilyar, sp. gr. 1.057. *Chiroli* abundant.

Darwari, $1\frac{1}{2}$ miles N.E. of Mural. Dry, except for pools of saturated brine, and the source of the salt sold at Dilyar. This *dhand* is a sheet of pure salt, surrounded by clusters of *chiroli* round its shores. Square cuttings are made in

¹ See ante, Chapter I, p. 212.

the salt, which are filled with saturated brine, from which the salt is allowed to recrystallise. The fresh salt is washed in the brine and piled in heaps, each heap being reckoned to be about 200 maunds in weight.

Dimanwari, 3 miles N.E. of Dilyar, sp. gr. 1.064.

All these *dhands* with the exception of Bangrio contain CO_2 equivalent to less than half a gram per litre of Na_2CO_3 . The amount of CO_2 in Bangrio works out at 1.2 grams of Na_2CO_3 per litre. I have not reproduced that part of the Sind map which shows the position of these *dhands*, since they are outside the alkaline area.

Samples of brine from the following *dhands* in the Diplo and Mithi taluqas in the south of the Thar and Parkar district were sent to me by the
Dhands of the Diplo and Mithi taluqas. Collector.—

Phangario, 4 miles N.W. of Rahim ki Bazaar, sp. gr. 1.101.

Mero, 24 miles S. of Islamkot, sp. gr. 1.206.

Khuraro, 3 miles E. of Rahim ki Bazaar, sp. gr. 1.065.

Lunkhan, 3 miles W. of Rahim ki Bazaar, sp. gr. 1.056.

Sikut, 2 miles N. of Rahim ki Bazaar, sp. gr. 1.206.

Jhu-jhu, 4 miles distant from Rahim ki Bazaar, sp. gr. 1.045.

Guni Belo, 28 miles S. of Islamkot, sp. gr. 1.204.

Rato, $2\frac{1}{2}$ miles E. of Balhari, sp. gr. 1.206.

The CO_2 of these *dhands* corresponds to less than 0.2 gram of Na_2CO_3 per litre.

From the foregoing account of the *dhands* of Thar and Parkar, it is now apparent that this area has been
 Summary. desiccated to a considerable extent since the canalisation of the Nara, so that without exception all the *dhands* worked for *chaniho* previously to 1899 are now dry, and can never yield again. Moreover, of the large *dhands* such as Sangriam, Badahu, Jakrao, etc., some are dry, and some are mere remnants of their former size.

It is clear also that the ancient limits of the alkaline region did not extend south of the latitude of Khipro, the most southerly *dhand*, Dabhiwari being highly saline. At present the most southerly alkaline *dhand* is Khari *dhand* in the S.E. part of Sanghar taluqa, while the only other *dhands* containing alkali in any quantity are Sukiawari, Nirawal, Bahanwari, and Gari, all being small *dhands* and all containing excess of chloride over carbonate. Khari, however, has

an excess of carbonate over chloride, and might yield a substantial deposit whenever it dries up sufficiently. There are then prospects of only a very small production of *chaniho* from the Sanghar taluqa, and no prospects of any production of *chaniho* from Khipro, nor, as far as we know, from any of the *dhands* in the southern taluqas, for it is to be assumed, since the *dhands* so far tested are saline, and since no one has ever heard of any alkali being produced from the *dhands* of the southern taluqas, that the area is one of salt and not alkaline deposits.

At the request of the Commissioner in Sind, samples of brine and of salt were sent to me from various deposits
 Moghal Bein area, and *dhands* near Shahbandar and Moghal Bein
 Karachi district. in the Karachi district. No alkali was found
 in the solid specimens, while the brines from the following *dhands*,
Kayur, Verh I, Verh II, Chach-Mumbrani, Sallawaro-Dhoro,
 were saline with less than 0.5 grams of Na_2CO_3 per litre.

CHAPTER VI.

CHEMICAL COMPOSITION OF EFFLORESCENT SALT AND MODE OF FORMATION; CHEMICAL COMPOSITION OF BITTERNS; ANALYSES OF *CHANIHO*.

The following are the results of the analyses¹ of eleven specimens of *reh* or *kalar* efflorescences collected from the shores of the Sind *dhands*.

Analyses of *reh* or *kalar* efflorescence.

TABLE VIII.—*Analyses of kalar from the Sind alkaline dhands.*

Area.	Name of dhand.	Total CO ₂	Cl	SO ₄	Na ₂ CO ₃	NaHCO ₃	NaCl	Na ₂ SO ₄
KHAIRPUR STATE I.—West Nara.	Mithri . .	14.6	21.5	10.60	27.0	12.8	35.4	15.7
	Galuwari . .	12.8	1.78	5.2	21.2	15.1	2.9	7.7
	Lahuri . .	12.5	1.6	5.3	20.1	16.0	2.6	7.8
II.—East Nara.	Drigwari . .	14.0	1.6	5.0	23.8	16.4	2.6	7.3
	Ashrafwari . .	14.0	1.8	5.1	22.8	17.2	2.9	7.5
	Kino Chaho . .	13.9	1.9	5.1	24.4	14.3	3.1	7.5
III.—Kot Jubbo NAWABSHAH DISTRICT.	Charakhwaro . .	13.0	1.6	4.9	21.7	15.1	2.6	7.2
	Kandiwaro . .	16.1	5.9	2.5	27.0	18.5	9.7	3.7
	Ridhwari . .	11.4	5.2	10.0	18.0	14.9	8.5	14.8
THAR AND PARKAR DISTRICT.	Khari . .	16.6	7.7	14.2	30.2	15.6	12.7	21.0
	Dangl jo Chahc . .	1.5	17.2	28.7	1.1	4.2	28.4	42.5

In the above analyses, only the acid radicles have been estimated and the amounts of sodium salts present are obtained by calculation on the assumption that the acid radicles are entirely combined with sodium. This is only approximately correct, since small quantities of potash are probably always present.

¹ The greater part of the analyses given in this chapter were done under the supervision of Mr. H. Walker, Curator, Geological Survey. The remainder including the estimation of bicarbonate were done by the following members of the Curator's Staff under my supervision—Babus B. B. Gupta, Sub-Assistant; B. C. Gupta, Assistant Curator; and Mahadev Ram, Laboratory Assistant, [G. de P. C.]

The following analyses have been done in the Geological Survey Laboratory. CO_2 and Cl have been estimated volumetrically, while SO_4 and total solids have been estimated gravimetrically. The estimation of bicarbonate has been according to a method described in the appendix to this chapter. The results are expressed in grams per litre.

TABLE IX.—*Analyses of bitterns of Sind dhands. (The figures represent grams per litre.)*

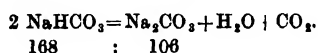
District.	Name of dhand.	Sp. Gr.	CO_2	Cl	SO_4	Total solids.
KHAIRPUR STATE, NARA AREA.	Sukohaho . . .	1.104	43.31	39.94	17.81	201.06
	Chughari Chahewari . . .	1.224	54.78	98.54	16.65	..
	Khariri Chachwari . . .	1.089	20.68	20.59	14.57	103.4
	I.—West of Nara					
	Mithri . . .	1.265	55.00	90.35	37.40	..
	Virhora . . .	1.025	6.07	5.15	1.41	24.90
	Dillahuwari . . .	1.024	5.19	2.13	2.30	21.86
	Gunjawari W. sim . . .	1.049	16.28	5.86	3.71	55.08
	Jatuwari . . .	1.191	58.96	35.86	24.43	233.0
	Khariri Mojanwari . . .	1.118	36.52	17.75	14.52	134.0
II.—East of Nara	Ganjawari . . .	1.164	37.40	56.09	16.87	208.65
	Lambro . . .	1.081	7.70	29.29	25.18	103.72
	Barko . . .	1.157	43.78	42.51	7.60	194.9
	Khara Okar . . .	1.151	47.74	22.11	18.93	177.1
	Sarwari . . .	1.049	13.97	5.68	4.95	50.0
	Moqamwaro . . .	1.127	43.56	16.51	9.76	145.45
	Sajdinwaro . . .	1.119	19.36	31.95	31.80	140.8
	Ussar . . .	1.031	8.18	3.55	2.89	30.1
	Motranwaro . . .	1.189	50.82	38.34	32.05	235.14
	Pakhyaro . . .	1.104	35.86	13.75	2.72	113.07
KHAIRPUR STATE, KOT JUDO AREA.	Gadanwar . . .	1.051	14.80	8.70	2.57	53.46
	Laiwari . . .	1.115	41.14	15.09	2.28	128.40
	Narui . . .	1.057	13.03	15.53	5.02	65.09
	Dabura . . .	1.059	14.19	18.37	1.58	67.73
	Savari Ulan . . .	1.044	10.61	15.25	0.22	59.90
	Turban . . .	1.045	13.31	7.90	0.12	46.55
	Sahal . . .	1.088	6.12	15.62	2.05	43.42

TABLE IX.—*Analyses of bitterns of Sind dhands — contd.*

District.	Name of dhand.	Sp. Gr.	CO ₂	Cl	'SO ₄	Total solids.
KHAIRPUR STATE, KOT JUBO AREA. — <i>contd.</i>	Machol . . .	1.009	1.89	1.20	0.14	6.86
	Padru . . .	1.029	8.21	3.73	0.29	26.45
	Kandiwaro . . .	1.025	6.01	6.76	0.86	26.70
	Lun Khan Ubrand . . .	1.035	5.12	15.97	1.26	39.34
	Bambalul . . .	1.084	23.08	12.57	6.13	95.00
	Leyara . . .	1.075	0.46	54.85	10.37	104.44
	Garho Got . . .	1.060	19.25	7.09	0.42	61.22
	Chandroi . . .	1.114	10.34	62.04	0.39	..
	Dukani . . .	1.069	19.64	16.86	2.63	79.02
	Pur Chandar . . .	1.070	19.75	17.57	2.73	79.88
	Kharro . . .	1.069	22.00	11.71	1.00	75.70
	Jhandol Wadi . . .	1.090	24.97	17.93	8.51	102.80
	Sanoi Wadi . . .	1.048	14.19	4.20	4.49	47.90
	Sanoi Kotonwari . . .	1.033	9.31	3.73	2.07	32.00
	Sanoi Garhi . . .	1.037	10.71	4.26	2.35	35.94
	Sanoi Narwarl . . .	1.046	13.75	5.50	2.90	46.77
	Gandhi . . .	1.087	28.27	16.86	Trace	98.56
	Kihri . . .	1.064	20.57	8.52	Trace	64.99
	Gabanwaro . . .	1.041	8.26	15.09	1.45	48.18
	Laniwari . . .	1.124	19.25	51.65	18.95	150.8
	Nau Rait . . .	1.172	50.60	20.91	23.61	207.70
	Rait Parlo . . .	1.037	3.56	17.39	4.44	43.98
NAWABSHAH DIS- TRICT, NASKAT TALUKA.	Khororo . . .	1.068	17.38	3.55	16.22	70.04
	Bolalu . . .	1.060	17.82	3.90	17.45	73.82
	Manakwari . . .	1.016	2.90	2.84	2.47	14.42
	Sanhri . . .	1.049	5.94	17.13	9.91	56.10
THAR AND PARKAR DISTRICT, BANG- HAR TALUKA.	Nirawal . . .	1.059	8.2	13.22	16.64	65.00
	Bahanwari . . .	1.054	8.49	14.91	10.47	60.00
	Suklawari . . .	1.021	2.49	6.21	3.69	21.32
	Gari . . .	1.154	23.32	43.49	47.83	195.78

Assuming that the base consists entirely of sodium (which however is not quite correct, since small quantities of potassium are probably present), I give below a table in which the above acid radicles are expressed as salts of sodium. The proportions of carb-

onate to bicarbonate have been calculated by a method described in the appendix to this chapter. The first column shows the number of grams per litre of NaHCO_3 , the second column the number of grams per litre of Na_2CO_3 , the third column shows the amount in grams of normal carbonate of sodium corresponding to the amount of bicarbonate present, according to the equation:—



The fourth column shows the total Na_2CO_3 present, and is the sum of the figures in columns 2 and 3. The fifth column shows the amounts of NaCl in grams per litre; the sixth the amount of Na_2SO_4 ; the seventh column shows the total sulphates and chlorides present, and is the sum of columns 5 and 6.

TABLE X.

Name of dhand.	NaHCO_3	Na_2CO_3	NaHCO_3 as Na_2CO_3	Total Na_2CO_3	NaCl	Na_2SO_4	Total NaCl and Na_2SO_4
Sukchaho . . .	..	..	..	111.56	65.84	26.84	92.18
Chughari Chahewari	17.64	120.84	12.01	132.85	154.12	24.62	178.83
Khariri Chachwari	9.24	43.99	6.29	50.28	33.94	21.55	55.49
Mithri . . .	13.44	124.02	9.15	133.17	148.05	55.30	204.25
Virchora . . .	7.56	9.86	5.15	15.01	8.49	2.09	10.58
Dillahuwari . .	6.38	8.48	4.34	12.82	3.51	3.40	6.91
Gunjawari W. sim .	26.88	22.26	19.61	41.87	9.66	5.48	15.14
Jasuwari . . .	23.56	124.02	19.45	143.47	59.11	36.13	95.24
Kharri Mojanwari .	15.12	78.44	10.30	88.74	29.26	21.47	50.78
Ganjawari	23.56	72.08	19.45	91.53	92.47	24.66	117.13
Landro . . .	8.23	13.35	5.60	18.95	48.28	37.24	85.52
Barko . . .	10.92	98.58	7.44	106.02	70.08	11.24	81.32
Khara Okar . . .	27.72	97.52	18.88	116.40	36.58	20.60	57.18
Sarwari . . .	12.18	25.97	8.29	34.26	9.36	7.82	16.58
Moqanwaro . . .	18.48	93.28	12.58	105.86	27.21	14.44	41.65
Baldinwaro . . .	15.96	36.57	10.87	47.44	52.62	47.02	99.69
Use . . .	7.40	15.05	5.04	20.09	5.85	4.28	10.13
Motganwaro . . .	23.66	108.12	15.44	123.56	68.20	47.89	110.59
Pakhyaro . . .	19.32	74.20	13.16	87.36	22.67	4.02	26.69
Gadanwari . . .	17.92	27.56	7.44	35.00	14.84	3.80	18.14
Ialwari . . .	24.26	83.74	16.59	100.83	24.87	3.27	28.24

TABLE X—*contd.*

Name of <i>dhanda</i> .	NaHCO ₃	Na ₂ CO ₃	NaHCO ₃ as Na ₂ CO ₃	Total Na ₂ CO ₃	NaCl.	Na ₂ SO ₄	Total NaCl and Na ₂ SO ₄
Narul . . .	10.29	24.91	7.01	31.92	25.60	7.42	33.02
Dabura . . .	10.50	27.56	7.15	34.71	30.29	2.26	32.55
Savari Ulan . . .	7.77	20.67	5.29	25.96	25.31	0.33	25.62
Turhan . . .	7.98	27.03	5.43	32.46	13.02	0.18	13.20
Sahai . . .	6.72	10.49	4.58	15.07	25.75	3.03	28.78
Machoi . . .	4.37	1.80	2.98	4.78	2.05	0.21	2.26
Padru . . .	6.97	15.37	4.75	20.12	6.15	0.43	6.58
Kandiwaro . . .	8.82	8.90	6.01	14.91	11.15	0.53	11.68
Lun Khan Ubrand .	6.47	8.27	4.41	12.68	26.34	1.86	28.20
Rambalul . . .	13.44	49.29	9.15	58.44	28.97	9.06	38.03
Leyara . . .	1.93	0.42	1.31	1.73	90.42	15.85	107.59
Garho Got . . .	14.23	37.36	9.72	47.08	13.24	0.64	13.88
Chandroi . . .	7.23	20.35	4.91	25.26	102.27	0.58	102.85
Dukani . . .	11.13	40.23	7.58	47.86	27.80	3.88	31.68
Pur Chandar . . .	9.87	41.34	6.72	48.06	28.97	4.04	33.01
Kharro . . .	15.12	43.46	10.30	53.76	19.31	1.48	20.79
Jhandol Wadi . . .	13.14	51.67	9.15	60.82	29.56	12.59	42.15
Sanoi Wadi . . .	13.02	25.97	8.87	34.84	7.02	6.64	13.66
Sanoi Kotenwari . .	7.81	17.49	5.32	22.81	6.15	3.06	9.21
Sanoi Garhi . . .	10.71	18.81	7.29	26.10	7.03	3.47	10.50
Sanoi Narwari . . .	12.18	25.44	8.29	33.73	9.07	4.42	13.49
Gandhi . . .	18.06	56.71	12.30	69.01	27.80	Trace	27.80
Kinri . . .	13.86	40.81	9.44	50.25	14.05	Trace	14.05
Gabanwaro . . .	6.05	16.96	4.12	21.08	24.87	2.14	27.01
Laniwari . . .	13.02	38.16	8.87	47.03	85.16	28.02	113.18
Nau Rait . . .	38.64	97.52	26.31	123.83	40.31	34.93	84.24
Rait Parlo . . .	4.87	5.51	3.32	8.83	28.68	6.56	35.24
Khororo . . .	4.20	39.22	2.86	42.08	5.85	23.99	29.84
Boiahu . . .	6.17	38.69	4.56	43.25	6.44	25.81	32.25
Manakwari . . .	9.16	1.22	6.24	7.46	4.68	3.65	8.33
Sanhri . . .	11.93	6.78	8.12	14.90	28.28	14.05	42.89
Nirawal . . .	11.93	12.30	8.12	20.42	21.80	24.61	46.41
Bahanwari . . .	10.92	13.57	7.44	20.91	24.58	15.48	40.06
Suklawari . . .	4.96	2.86	3.38	6.24	10.24	5.76	16.00
Gari . . .	20.16	43.46	13.73	57.19	71.69	70.72	142.41

From the above analyses it will be seen that while the *dhands* of the Nara region are typical "triple" waters containing mixtures of sulphate, carbonate, and chloride, those of the Kot Jubo area are more of the carbonate-chloride type with subordinate amounts of sulphate.

Laniwari, Nau Rait, and Rait Pario are exceptions to this, being "triple" waters, while Leyara is a sulphato-chloride *dhand*, as is also Lambro.

Laniwari, Nau Rait, and Rait Pario lie in the more open country north of the great sand-plateaux or *dra-ins* of Pur Chandar and Sanoi; it may then be said that those *dhands* which are in close association with the *dra-ins* are of the carbonate-chloride type or tend to that type, while those of the open country composed of *blit* and *tali* tend to be of the "triple" type.

The proportion of carbonate to chloride in the *dhands* is much lower than it is in the efflorescence. This means that the *sim* or percolating water carries greater quantities of chloride than the efflorescence which it causes. We would naturally expect this to be the case, since the predominance of carbonate in the efflorescence is due to fractional crystallisation, whereby trona is deposited (or sodium bicarbonate), while a large part of the chloride stays in solution.

The following are the analyses of the specimens of *chaniho* collected.

The last column shows the quotients obtained by dividing the quantity of sodium carbonate present by the amount of sodium bicarbonate. This may be called the "carbonate-bicarbonate index."

The theoretical carbonate-bicarbonate index in trona is 106/84 or 1.262. In practice, in natural trona the carbonate-bicarbonate index appears never to be quite so low as the theoretical value. The index for the trona of the Lonar Lake (*dulla*), calculated from F. J. Plymen's analysis given in La Touche and Christie's paper¹ is 1.413.

In the above analyses, the indices in the cases of fourteen *dhands* are below 1.600. The *chaniho* of these fourteen *dhands* may be regarded as trona, not altogether pure perhaps, but still trona.

TABLE XI.—Analyses of specimens of chaniho from the Sind dhands.

Area.	Name of dhand.	CO ₂ per cent.	Cl per cent.	SO ₄ per cent.	Na ₂ CO ₃ per cent.	NaHCO ₃ per cent.	NaCl per cent.	Na ₂ SO ₄ per cent.	Carbonate- bicar- bonate. Index.
Khairpur State	Bagarwaro . . .	18.48	5.3	19.3	33.4	17.6	8.8	28.6	1.895
	Sukohaho . . .	26.18	3.6	3.1	44.5	29.4	5.8	4.5	1.514
	Dosewari . . .	20.24	9.3	9.6	33.7	23.9	15.4	14.2	1.406
	Mithri . . .	24.64	2.7	7.4	41.9	27.7	4.4	10.9	1.510
	Chilhanwaro . . .	19.80	2.7	20.2	34.4	21.0	4.4	29.9	1.640
	Khari Mojanwari . . .	27.50	1.1	2.9	45.6	32.8	1.8	4.3	1.391
	Lalri Wadi . . .	24.64	5.5	4.6	41.3	28.6	9.1	6.8	1.447
	Lambro . . .	8.58	0.4	51.3	19.9	1.3	0.6	76.0	15.777
	Ganjawari . . .	24.64	4.1	3.8	41.3	28.6	6.7	5.6	1.447
	Khabbarwaro . . .	21.34	3.5	14.9	36.0	24.4	5.8	22.0	1.479
	Barko . . .	25.52	3.9	12.5	53.5	12.6	6.4	18.5	4.248
	Buxahu . . .	25.85	2.0	4.0	42.1	31.9	3.4	5.9	1.20
	Pakhyaro . . .	27.61	2.2	0.8	45.6	33.2	3.7	1.2	1.373
	Ganwarwaro . . .	25.63	1.7	8.7	48.2	21.4	2.8	12.9	2.251
	Nainwaro . . .	14.95	2.3	35.8	26.5	15.1	3.8	53.0	1.751
Nawabshah District.	Gadanwari N. . .	28.38	0.7	0.1	47.2	33.6	1.2	0.2	1.404
	Laiwari . . .	28.33	0.7	0.3	39.3	30.0	1.2	0.5	1.641
	Suji . . .	27.28	2.1	0.9	45.0	32.8	3.5	1.3	1.374
Thar and Parkar District.	Kilanwari . . .	22.22	1.3	6.8	35.5	28.6	2.2	10.1	1.243
	Phogwari . . .	14.30	4.4	24.0	23.8	16.8	7.3	35.5	1.411
	Akanwari . . .	26.29	3.9	6.9	45.0	29.0	6.4	10.2	1.554
Thar and Parkar District.	Dabhiwari . . .	0.77	0.5	60.2	0.5	2.1	0.9	89.1	0.252

In the cases of Lambro, Nainwaro, and the old *chaniho* heaps of Dabhiwari, the so-called *chaniho* is mainly sulphate; the alkali in the *chaniho* of Lambro must be largely natron or a partially dehydrated product of natron.

The analysis of the Barko *chaniho* is interesting. We have seen from the analysis of the water of Barko that the *dhand* is deficient in bicarbonate. In consequence, the *chaniho* of Barko is largely normal carbonate, which must have crystallised as natron from the *dhand*.

The *chaniho* of Ganwarwaro was collected from the dried up *dhand*, and represents the solid residue of the total dissolved salts. The *chaniho* of Laiwari appears to have been collected from dried up pools at the sides of the *dhand*. The *dhand* itself, from which a specimen of water was taken, did not dry up at all. Consequently the *chaniho* of this *dhand* represents an impure residual deposit.

The *chaniho* of Bagarwaro is also an impure deposit.

I have remarked in chapter II that there were from 8,000 to 9,000 maunds of *chaniho* on the southern shore of Lambro, which was of "second grade" quality. That is to say, it is classed as second grade by the local people. It is however impossible to see how Lambro could produce anything except a largely sulphatic deposit, considering the analysis of its water (see *ante*). The classing into grades appears to be a purely physical classification based upon the hardness and texture of the deposit, and freedom from solid impurities, such as sand. No one seems to be able to distinguish sulphate from carbonate of soda.

The specimens analysed above are not average samples, but are pieces picked at random from one of the *chaniho* stacks. Before collection, they had been exposed to the dry air and sun's heat for several months, and probably lost some of their volatile constituents.

It is perhaps worth while to recapitulate briefly the various views put forward regarding the formation of

Formation of alkaline carbonates.

alkalis in desert regions. It is generally recognised that efflorescent salt characterises arid areas of imperfect drainage where water rising to the surface by capillary attraction is evaporated, leaving its burden of dissolved salts as a crust on the surface of the soil. This crust is known in North West India as *reh*, and in Sind as *kalar*. Land rendered barren by the presence of such salts is termed *usar* land. Analyses

of *reh* from *usar* lands in the United Provinces are given by J. W. Leather.¹ The deposit consists of the four salts, sodium carbonate, bicarbonate, sulphate, and chloride in very varying proportions, and the analyses are very similar to those given above of the efflorescent salt from the Sind *dhands*. W. Center² discusses the mode of formation of *reh* and inclines to the view that the alkaline carbonates are derived from rock decomposition, the sodium being derived from such minerals as felspar which are acted on by water with carbon dioxide in solution.

Efflorescent salts of a very similar type are found in the desert regions of the United States, where they have been investigated very carefully by the scientists of that country. Analyses and a resumé of the various hypotheses of their formation are given by F. W. Clarke.³ Clarke explains the alkalis of the Lahontan waters in Nevada as a concentration of leached material from the igneous rocks of the neighbourhood,—a view that may be compared with that of W. Center in the case of *reh*. La Touche and Christie,⁴ in their account of the alkaline lake at Lonar in Berar, adopt a similar explanation. The chief difficulty in the way of accepting this view is the fact that in all these alkaline deposits, large quantities of chloride are associated with the alkali. It is not easy to account for the chloride as due to the breaking down of rock-forming minerals, since, as W. Center and others have pointed out, the percentage of chlorine in the different classes of rock is extremely small.

Those authorities who have explained the origin of the carbonate in the manner outlined above have found it necessary to seek a different origin for the chloride, which the majority appear to regard as ultimately derived from the sea. The necessity of supposing different origins for these two associated salts is a stumbling-block in the way of full acceptance of these views.

Accordingly other hypotheses have been put forward, which are not open to this objection. A view developed by T. Sterry Hunt,⁵ E. von Kvassay,⁶ E. W. Hilgard,⁷ and by G. Schweinfurth and R. Lewin,⁸ supposes that the sodium carbonate of alkaline lakes

¹ "Investigation on *Usar* Land in the U. P.," Allahabad, 1914.

² W. Center, *Rec. G. S. I.*, XIII, p. 253.

³ F. W. Clarke, "The Data of Geochemistry," *Bull. U. S. Geol. Sur.*, No. 616.

⁴ *Rec. G. S. I.*, XLI, p. 266.

⁵ *Am. J. Sci.*, 2nd Ser., vol. 28, p. 170.

⁶ *Jahrb. K.-k. Geol. Reichsanst.*, 1876, p. 427.

⁷ *Am. J. Sci.*, 4th Ser., vol. 2, p. 123.

⁸ *Zeits. Gesell. Erdkunde*, vol. 33, 1898, p. 1.

is due to reactions between calcium bicarbonate, salt, and gypsum, the last two substances reacting to form calcium chloride and sodium sulphate; the sodium sulphate thus formed is supposed to exchange with calcium bicarbonate to produce alkali. Lastly a view put forward by E. Sickenburger may be mentioned. In a paper dealing with the alkaline lakes of Egypt,¹ he suggests that the carbonates are derived through the reduction of sulphates by organic matter such as algae, which are abundant in the Egyptian lakes.

I have had little time to investigate this question. Nevertheless I should like to put forward tentatively the conclusions to which I have come. I feel difficulty in accepting W. Center's hypothesis for several reasons, first because there are no rocks in the immediate neighbourhood of these alkaline lakes of Sind, and the nearest rock—the limestones of Rohri and Sukkur—cannot be supposed to contain any appreciable quantity of alkaline silicates. Secondly the alkaline region is very limited in extent, and is surrounded by a saline region; if however the alkali was really due to the decomposition of more distant rock-masses such as the Himalaya, or the Archæan complex of Rajputana, how are we to explain the peculiar limited geographical distribution of the alkaline lakes?

These considerations, as well as the fact that there are very large quantities of salt both in association with the alkali and in the country immediately surrounding the alkaline area,² lead me to suppose that a hypothesis such as that of Sickenburger is preferable in the case of the Sind *dhands*. I think however that the fact that the efflorescences from the *sim* or percolating water contain large quantities of carbonate shows that the conversion of sulphates to carbonates cannot be produced by the decomposition of algae in the lakes, but has taken place before ever the salts reached the lakes, and while they were actually dissolved in the percolating water. The decomposition is of course carried on by bacterial action, and it seems reasonable to suppose that the carbonates derive their carbon from the decomposition of organic matter, as has been suggested by Sickenburger. I see no necessity for the hypothesis put forward by some authorities that the carbon is derived from the breaking down of calcium carbonate.

¹ *Chem. Zeit.*, 1892, pp. 1645—1691.

² See Blanford, *Rec. Geol. Sur. Ind.*, X, p. 10; also Le Touche, "Geology of Western Rajputana," *Mem. Geol. Sur. Ind.*, XXXV.

Assuming then that sodium sulphate is formed in the manner suggested by Schweinfurth and Lewin (see above), we have to consider whether the peculiar conditions in the Sind desert favour the further transformation of sulphate into carbonate by bacterial action as Sickenburger supposes is the case in Egypt.

The following points seem to be of importance in this connection :-

- (1) The alkaline *dhands* derive their water supply invariably from *sim* or percolating water coming from beneath the desert sand.
- (2) The soil associated with this *sim* water is of a very dark colour, and has a carbonaceous appearance.
- (3) The alkaline *dhands* have a peculiar and offensive smell and in this respect differ markedly from the saline *dhands*.
- (4) They contain bacteria of a peculiar type. Specimens of the bitterns were taken by me in December 1918, placed in spring stoppered bottles with rubber fittings (and therefore air-tight), and sent to the Geological Survey Laboratory for testing. With the exception of an hour or so, when the bottles were opened in order to take out samples for testing, they were kept air-tight till September 1919,—a period of eight months. Nevertheless the bacteria were still vigorous, and were found still living in such strong bitterns as Mithri and others of similar high specific gravity. The discovery of bacteria in these bitterns is due to Dr. Annandale, who kindly examined several bottles. Captain R. S. Sewell, I.M.S., also kindly examined some samples for me. The bacteria appear to be anærobic, but they have not been identified with any known type, and it would be exceedingly interesting to study them further. I am not myself qualified to undertake this, but I hope at some future time that the matter may be investigated by a bacteriologist.

I then seek an explanation of these alkaline *dhands* in the peculiar conditions of the Sind desert, where a flat alluvial plain, probably fertile formerly (or at any rate as fertile as the plain west of the Nara), is now completely covered by wind-blown desert sand. The alluvial clay is fairly impervious to water. This is a fact well

known to the Irrigation Department, who have estimated the loss of water through the banks of such canals as the Jamrao, where it passes through the sand-hills, and the almost negligible loss through the canal banks where it passes through alluvial clays. It seems clear that the alluvial clays beneath the desert sand hold up the rain water, so that a moist layer is formed at the base of the sand. The numerous *kochur*, and pools in deep hollows in the sand-plateaux, I think, prove this. It is also obvious that the *dhands* derive their water from the basal layers of the sand-hills around them, since in many places there are small pools of water and moist ground along the shore of the *dhand*, the level of the water-pools being one or two feet above that of the *dhand*. These pools are often filled with drinkable water, while the water of the *dhand* may be unfit even for cattle.

This moist layer of basal sand is doubtless full of organic matter, due to the remains of the vegetation which formerly covered the alluvial plain. It is also protected from the air and from an oxidising environment by the cap of sand. Such conditions are exceptional. They are very different from those prevailing below the level of permanent saturation in cultivated country. Water below the level of permanent saturation in ordinary alluvial plains is subject to very little movement, if indeed any. Such chemical changes as go on below the level of permanent saturation appear to be of the type associated with a reducing environment, but the changes are necessarily slow processes. Most moving water in ordinary alluvial country appears to become oxidised at some time or other, and the abundance of *kankar* nodules in the old alluvium is evidence of this. But in the Sind desert there is a stratum of flowing water, which is yet very well protected from the air. It appears to me probable that in this circumstance is to be found the explanation of the alkaline lakes of Sind.

APPENDIX.

ON THE ESTIMATION OF CARBONATES AND BICARBONATES IN TROPICAL CLIMATES.

It was found impossible to obtain accurate results from the use of Winkler's method, as given in the text-books.

An attempt was made, using a modification of Winkler's method as described by F. K. Cameron,¹ but even on the same solution no two results were alike.

The cause of the varying inaccuracies is the high temperature of Calcutta in the hot weather. It is possible however to work Winkler's method in the cold weather.

In the hot weather temperatures of 80° or 90°, perhaps even 100° Fahrenheit, the standard solution from the burette, when admitted slowly into the liquid causes local supersaturation, and some CO₂ inevitably escapes, before all the carbonate has been converted into bicarbonate.

In estimating the bicarbonates and carbonates, I followed very closely the method adopted by F. K. Cameron, using very small quantities of indicator, titrating to the *first* change of colour of the methyl orange, and to complete loss of colour of the phenolphthalein. I modified his method in the following manner :—

Using a burette, not fitted with a glass stop-cock, a rubber tube of $\frac{3}{16}$ " bore about 16 inches long was fastened to the end of the burette. The lower end of the rubber tube was fitted with a glass nozzle.

An Erlenmeyer flask of 350 c. c. capacity was now fitted with a rubber cork in which two holes were drilled close together. Through one hole the glass nozzle which conveys the liquid from the burette was inserted. Through the other was inserted a short piece of glass tube, about two inches long, of which about $\frac{3}{4}$ inch protruded from the top of the cork. This was fitted with a short piece of rubber tubing about 2 $\frac{1}{2}$ inches long.

A large pinch-cock was now fitted, so that it controlled both the rubber tube from the burette, and the short rubber tube fitted to the short glass tube which passes through the rubber cork. The burette was now filled with standard KHSO₄, and the liquid to be titrated was placed in the Erlenmeyer flask. The cork was fitted, and the standard solution admitted slowly. Every now and then the pinch-cock was closed, whereby the flask was completely sealed and the flask was rotated with a circular motion. In this way any CO₂ which has escaped into the air inside the flask is not lost, but is re-absorbed into the liquid so long as any normal carbonate remains. Absorption is aided by the warm temperature of the laboratory.

¹ F. K. Cameron. "Estimation of Carbonates and Bicarbonates in Aqueous Solution", *U. S. Dept. of Agriculture, Div. of Soils, Bull.* 118, 1901.

This method prevents any loss of CO_2 . It was checked by titrating pure sodium carbonate, when it was found that exactly half the quantity was required to the end-point of the phenolphthalein. There are still difficulties in using this method of testing, as the personal equation enters largely into the determination of the end-points, which are difficult to fix. It is necessary to practise first upon pure sodium carbonate before titration, to use very minute quantities of indicator, to take the same amounts of solution and as nearly as possible the same strengths of alkali, and to use the same number of drops, (not more than two, preferably one) of indicator in each experiment. Titration must be carried on exactly to the end-points indicated in F. K. Cameron's paper, viz., to complete loss of colour of the phenolphthalein, and to the first change of the methyl-orange.

CHAPTER VII.

PRODUCTION OF *CHANIHO* IN SIND; CURRENT PRICES; GRADES OF *CHANIHO*; METHODS OF COLLECTING; PRICES OF SODA-ASH AND CONSUMPTION OF SODA IN INDIA; CONCLUSION.

The earliest returns which I have been able to obtain date from 1895 to 1900. These are given in a memorandum by the Commissioner in Sind, No. C-319, dated 2nd May 1900. The returns are given in figures which evidently represent maunds, although the unit has been omitted from the copy of this letter shown to me. Separate returns are given for *kharo* (crystalline trona) and for *phuli* (efflorescent impure trona).

TABLE XII.—*Output of chaniho in Khairpur State from 1895 to 1900.*

Season.	Kharo Chaniho.	Phuli.	TOTAL.
1895-96	68,529	4,540	73,069
1896-97	78,471	387	78,858
1897-98	28,143	1,008	29,151
1898-99	34,524	6,726	41,250
1899-1900	59,895	945	60,840

Total for five years :—283,168. Average yearly production :—56,633.

This average yearly production works out at 2,089 tons of trona per annum, which corresponds to probably about 1,000 tons of soda-ash. Pure trona ought to contain 70·3 per cent. of anhydrous sodium carbonate, but the commercial trona of Sind is never pure; consequently it may be regarded as certain that 2,089 tons of trona correspond to considerably less than 1,468 tons of Na_2CO_3 . The figure is therefore nearer to 1,000 tons.

The returns of *chaniho* in recent years from Khairpur State are difficult to interpret. The unit of weight adopted is the *mani*. According to the Report of the Weights and Measures Committee, 1913-1914, 1 *mani* is equivalent to 12 maunds (1 maund=82 $\frac{2}{3}$ lb.).

In the returns of *chaniho* production obtained from the Khairpur State, there is however a footnote stating that "Each *mani* contains about 9 maunds." I wrote to the Political Agent, Khairpur State, to ascertain the exact value of the *mani* in that state, and received a reply from the Vazir, in which he says that "a *mani* is held to be equivalent to 9 maunds, as is noted in a foot-note...."

The Khairpur *mani* must then be regarded as equivalent to 9 maunds (1 maund=82 $\frac{2}{3}$ lb.).

I have on my files two sets of returns of *chaniho* from the Khairpur State. The first list accompanies a letter dated 2nd November 1918 to the Political Agent, Khairpur State,¹ but I am informed by the Vazir,² that it was reproduced from a list accompanying a previous letter dated the 25th October 1917.³ The second list accompanies a letter to the Commissioner in Sind, and is dated the 16th January 1918.⁴ It is therefore the later of the two lists, and I am informed by the Vazir that the later list is the more accurate of the two. I therefore reproduce the later list below. I have given in column 2 the revised spelling of the *dhands* adopted in this Memoir, and at the end of the table the totals in *manies* and in maunds.

TABLE XIII.—Output of *chaniho* in Khairpur State from 1912-13 to 1916-17.

Name of <i>dhand</i> .	Spelling in this Memoir.	1912-13 "manies."	1913-14 "manies."	1914-15 "manies."	1915-16 "manies."	1916-17 "manies."
White Bitiro . .	Achro Bitiro . .	4	..	..	..	..
Lahuri . . .	Lahuri . . .	4	..	..	..	..
Dall . . .	Dall . . .	159	..	12	..	70
Chara khanwala Great.	Charakhanwaro Wado.	..	..	8	..	..
Guloo Wall . .	Galuwari . .	..	..	160	..	..

¹ Letter No. 3398, dated 2nd November 1918, from the Vazir of Khairpur to the Political Agent, Khairpur State.

² Letter No. 1818, dated 17th June 1919, from the Vazir of Khairpur to myself.

³ Letter No. 3903, dated 25th October 1917, from the Khairpur State.

⁴ Letter No. 255, dated 16th January 1918, from the Khairpur State to the Commissioner in Sind.

TABLE XIII.—*Output of chaniho in Khairpur State from 1912-13 to 1916-17—contd.*

Name of dhand.	Spelling in this Memoir.	1912-13 "manies."	1913-14 "manies."	1914-15 "manies."	1915-16 "manies."	1916-17 "manies."
Ashrafwala . .	Ashrafwaro . .	..	12	..	..	..
Lalri Great . .	Lalri Wadi . .	84	..	12	..	75
Dherloon . .	Dherlun . .	16	..	..	..	..
Sukchahow . .	Sukchaho . .	..	..	..	..	300
Saidahoo . .	Saidahu . .	25	12	..	..	..
Taraie Bharkow . .	Tarai Barko . .	4	..	..	..	..
Pharanwala . .	Pharanwari . .	..	..	..	..	15
Khari Mojanwali . .	Khariri Mojanwari . .	44	..	..	..	..
Chughiri Kalarwari . .	Chughari Kalarwari . .	16	..	..	..	..
Kara Oker . .	Khara Okar . .	32	..	..	..	..
Western Dabanwali . .	West Dubranwari . .	..	300	25	..	300
Tarai . .	Taraiwari . .	..	..	..	150	..
Bharkow . .	Barko . .	..	..	..	1,255	400
Parowali . .	Paruwari . .	44	100	152	30	..
Whichonoro . .	Virchora . .	6	..	..	..	..
Chughari Chahowali . .	Chughari Chahewari . .	..	..	..	..	60
Digh . .	Drigwari . .	..	100	..	..	..
Noganwala . .	Nanganwaro . .	6	..	..	..	..
Jatowali . .	Jatuwari . .	..	..	70	..	30
Lalri Lumbrewali . .	Lalri Lambrewari . .	..	..	..	..	20
Bartkon . .	Bartako . .	22	..	..	..	..
Tikini . .	Tikini . .	19	..	4	..	..
Kino Chaho . .	Kino Chaho . .	12	..	..	..	..
Bagarwala . .	Bagarwaro . .	210	..	..	..	20
Methari . .	Metahari . .	30	80	120	..	80
Kalarwali . .	Kalarwari . .	..	..	..	..	4
Eastern Dabanwali . .	East Dabranwari . .	..	..	155	65	60
Kakaranwala . .	Kakaranwaro . .	75	..	..	..	..
Bolahwali . .	Bulahwari . .	7	120	150	..	32
Chilh . .	Chilhanwari . .	40	..	..	..	..
Mat Walo . .	Matiwaro . .	4	..	..	..	25
Lalri Small . .	Lalri Sanhri . .	13	..	22	..	..
Lambrow . .	Lambro . .	..	..	600	..	..
Buxahoo . .	Buxahu . .	..	..	..	150	60
Hasari . .	Hasari . .	54	6	..	..	..

TABLE XIII.—Output of ohaniho in Khairpur State from 1912-13 to 1916-17—*contd.*

Name of dhand.	Spelling in this Memoir.	1912-13 "manies."	1913-14 "manies."	1914-15 "manies."	1915-16 "manies."	1916-17 "manies."
Khabarwala . . .	Khabarwara . . .	258	..	..	..	45
Small Charaganwala	Charakha n w a r o Nandho.	8	..	..	..	..
Gango . . .	Ganjawari . . .	..	..	..	405	325
Khari Chachwali . .	Khariri Chachwari .	1	..	..	..	..
Boogi . . .	Bujiwari . . .	14	..	..	..	..
Mithari . . .	Mithri . . .	..	..	..	250	200
Mirwali . . .	Mirwari . . .	8	..	..	..	..
Doso Wali . . .	Doscwari . . .	51	..	45	20	..
TOTAL PRODUCTION, NARA REGION . . .		1,270	738	1,527	2,325	2,124
KOT JUBO REGION.						
Pakhiaro . . .	Pakhyaro . . .	..	..	..	500	100
Niblowie . . .	Bambalul . . .	20	..	..	..	..
Lais Wala . . .	Laiwari . . .	..	..	..	280	..
Phuloowala . . .	Kalbuwara . . .	32	..	..	..	..
Gabanwala . . .	Gabanwara . . .	100	..	..	..	..
Rait Parlo . . .	Rait Parlo . . .	810	140	12	..	..
Snowie Great . . .	Sanoi Wadi . . .	..	..	12	128	..
Snowie Red . . .	Sanoi Garhi . . .	..	..	8	108	..
Jhandole . . .	Jhandol Wadi . . .	..	..	..	40	..
Rait New . . .	Nau Rait . . .	..	..	..	36	4
Gandhi . . .	Gandhi . . .	..	..	..	24	..
Kandriwala . . .	Kandiwaro . . .	15	..	..	..	..
Kote Korow . . .	Kot Korro . . .	..	75	..	..	..
Reddish Got . . .	Garho Got . . .	..	25	..	..	..
Dabhow . . .	Dabho . . .	..	..	..	80	1
Kharrow . . .	Kharro . . .	..	..	7	32	..
Padrew . . .	Padru . . .	..	..	..	5	..
Snowie Kotenwali . .	Sanoi Kotenwari . .	..	..	..	125	8
Snowie Narwali . . .	Sanoi Narwari . . .	..	..	173	..	35
TOTAL PRODUCTION, KOT JUBO REGION . . .		1,067	240	206	1,358	233
GRAND TOTALS IN MANIES . . .		2,337	978	1,733	3,683	2,357
EQUIVALENTS IN MAUNDS . . .		21,032	8,803	15,597	33,147	21,213

TOTAL FOR FIVE YEARS 99,792 MAUNDS. AVERAGE YEARLY PRODUCTION, 19,958 MAUNDS.

The average annual production during the quinquennium ending 1917 thus works out at only 734 tons of trona, an amount corresponding to less than 500 tons of sodium carbonate.

The reasons of the very marked fall in production in the quinquennium ending 1917, as compared with the quinquennium ending 1900, I am unable to state.

Production of *chaniho*
from Nawabshah district.

Returns for the seasons 1915-16, and 1916-17 are the only ones I have been able to obtain from the Nawabshah district. The following were the quantities of trona obtained :—

	Maunds.
1915-16	10,215
1916-17	4,775

The Collector of Nawabshah remarks¹ that “the marked decrease in the output of ‘chaniho’ during the year 1916-17 is due to heavy rains, in consequence of which the tanks (*i.e.*, *dhands*) could not be worked for full three months, *viz.*, July to September 1917 out of a season of seven months, April to October, during which the deposits are ordinarily worked.”

Since Khairpur and Nawabshah district are the only areas which now produce *chaniho*, (the Thar and Parkar production having ceased since 1899, as has been explained in Chapter V), the total production for Sind can be obtained by adding the Nawabshah production to that of Khairpur. The following are therefore the figures for the total Sind production for 1915-16, and 1916-17.

	Maunds.
1915-16	43,362
1916-17	25,988

The Collector of Nawabshah¹ states “There is very little local demand for the commodity. Almost the whole of it is exported to Karachi and Sukkur, where it is used for washing and dyeing purposes, for purifying molasses, and for soap-making. The product (*i.e.*, of Nawabshah

¹ Letter No. 3039 Rev. Dept., dated 15th October. 1917, from A. W. Mackie, Esq., I.C.S., Collector of Nawabshah District, to the Commissioner in Sind.

district) is not of that superior variety which is used in Sind for the preparation of pulse-cakes, and which is obtainable from the Khairpur State."

The Sind Gazetteer notes that the purer *chaniho* from the Khairpur State is exported to Bombay. Mr. Thurley made enquiries in the Karachi Bazaar, and writes "Except for a negligible quantity that is disposed of in Sind, the whole of the *chaniho* goes to Bombay or Basra. How much to each of these two places I cannot say."

The export figures for *chaniho* from Karachi for the years 1915-16 and 1916-17 are given below :—

TABLE XIV.

—	1915-16.		1916-17.	
	Cwts.	Rs.	Cwts.	Rs.
Exports to foreign countries	7,483	44,897	5,723	34,340
Exports to coast ports . .	7,036	42,219	11,885	71,310
TOTAL .	14,519	87,116	17,608	1,05,650
TOTALS IN MAUNDS .	Mds. 19,760	...	* Mds. 23,964	...

Comparing these figures with those of production for the years 1915-16 and 1916-17, it is evident that over 63 per cent. of the *chaniho* is exported, presumably mainly to Bombay and Basra.

The uses of *chaniho* are stated in a letter from the Assistant Commissioner in Sind to be—

for washing and dyeing clothes ;
 for hardening treacle ;
 for converting sugar-cane into molasses ;
 in flavouring the preparation from tobacco called *goorakho* ;
 and principally as a yeast in the preparation of *papars* or pulse-biscuits to make them light, crisp, and digestible.

* Letter No. Exc. 396, dated 22nd Aug. 1917.

Mr. Mahommed Khan, the Khairpur State official, who accompanied me on my tour through the State, recognised three grades of *chaniho*, the distinctions between each grade being purely physical. The first grade is crystalline and light; the second grade is more powdery and is derived from a deposit in which efflorescence is common as well as crystalline deposition. The third grade is heavy owing to the presence of sand mingled with the *chaniho*. These three grades are grades of what is known as *kharo saf* or pure trona, as distinguished from *kharo lunial*, which according to Mr. Mahommed Khan is not produced by the State. *Kharo lunial* or salty trona is a term formerly applied to the very impure salty residues from the Thar and Parker *dhands*.

In the Haidarabad bazaar four grades of *chaniho* are sold. Specimens of these were forwarded to me by the Collector. The following are their partial analyses:—

TABLE XV.—*Analyses of specimens of the four grades of chaniho sold in the Haidarabad bazaar.*

—	CO ₂	NaHCO ₃ *	Na ₂ CO ₃ *	Cl	NaCl*	Residue insoluble in water.
Grade I . .	31.5	11.8	68.4	1.45	2.4	6.52
Grade II . .	36.0	3.4	84.5	1.19	2.0	3.40
Grade III . .	23.4	0.4	56.2	13.70	22.6	5.04
Grade IV . .	30.9	0.4	74.2	2.84	4.7	3.92

* Calculated, assuming the base to be Na.; Na₂SO₄ was not estimated.

There is not much to be gained in studying the chemical composition of these four grades. Undoubtedly the third grade is chemically inferior, but there is not much to choose between the first, second and fourth. It must however be noticed that the first grade is the only one suitable for use as a baking powder.

Here again the distinction between the four grades is purely empirical and physical. I have made the following notes on the four grades—

Grade I.—A hard white crystalline cake, fairly pure in appearance and free from dirt.

Grade II.—Broken in small pieces, very vesicular, although crystalline in parts, and of a good white colour.

Grade III.—Broken in small pieces, vesicular, of a dirty colour, and more impure in appearance.

Grade IV.—Broken in small pieces, of a still dirtier colour than III, and apparently more impure.

The analyses of *chaniho* given in Tables XI and XV show how very variable is the composition, so that Quality of *chaniho*. it is mainly a matter of chance whether the *chaniho* sold is over 90 per cent. carbonate or 50 per cent. sulphate. No one seems to be able to recognise the existence of sodium sulphate as a separate and distinct compound from salt and trona. Some of the Sindhi villagers appear to think that it is a mixture of the two latter, because its taste is feebly saline. Doubtless they are content to use such poor stuff as the so-called *chaniho* of Lambro or Nainwaro for their domestic use, having a prejudice, like all lovers of their country, for their own good old Sind *chaniho*, which has been used by their forefathers from time immemorial.

The analyses of *chaniho* in Table XI show however what sort of quality of trona may be expected, provided a scientific scrutiny is exercised over the deposits. Some of the trona, such as that of Laiwari, Gadanwari, and Pakhyaro, seems to be quite high enough in carbonate to put on the modern market, but it can hardly be a wise policy to mix such sulphatic deposits as those of Lambro with the purer trona of other *dhands*, since the modern world is now-a-days quite expert enough to form a correct opinion of the quality of the articles they buy, and to refrain from buying the inferior article.

In 1900, the bazaar prices for *chaniho* were as follows:—
Prices of *chaniho*.

Grade I, packed in wooden boxes, known as *papar-khar*, per maund Rs. 3-12 to Rs. 4.

Grade II, known as *Gulahi*, per maund Rs. 2-10.

Grade III, per maund Rs. 2-4 to Rs. 2-6.

The Thar and Parker *chaniho* used to be sold at Re. 1-8 for the better quality, and Annas 10 for the inferior quality.

In 1917 the bazaar prices in Karachi were¹ from Rs. 2 to Rs. 5 per maund *wholesale* up to Rs. 10 per maund *retail*.

¹ Letter No. Exc. 396, dated 22nd Aug. 1917.

Mr. R. E. Gibson, I.C.S., Collector of Haidarabad, who sent me the four specimens of grades of *chaniho* from the Haidarabad bazaar mentioned above, informs me that the bazaar prices were in 1919 :—

	Rs.
Grade I	14
Grade II	12
Grade III	8
Grade IV	4

The retail price of *chaniho* has therefore, like that of all other commodities, risen during the war.

Sind however consumes but a fraction of the total *chaniho* produced, and for the remainder which is exported wholesale rates at a very much lower scale are obtained. Mr. E. L. Thurley informs me that the price wholesale in Karachi, appears to fluctuate, as far as he can ascertain, between Re. 1-8 and Rs. 2 per maund, but he says that his information was given him casually in conversation and, not being based on accurate study of figures, may not have been quite reliable. His figures are lower than those in Table XIV where *chaniho* is valued at Rs. 6 per cwt. or Rs. 4-6 per maund. The prices quoted by Mr. Thurley are more likely to be the prices paid at the *dhands*, where the *chaniho* is bought by Bombay merchants, who export it to Karachi and Bombay. The usual practice appears to be purchase at the *dhands* themselves by the merchants from Bombay or elsewhere who require it. They then export the *chaniho*, without resale in Karachi.

Mr. Mackie¹ states that the average selling price during the seasons 1915-16 and 1916-17 was Re. 1-7 per maund in Karachi and Sukkur.

At Akanwari *dhand* the *chaniho* was said to fetch about Rs. 9 to Rs. 10 per mani, or Re. 1 to Re. 1-2 per maund, but the best quality has fetched as much as Re. 1-14.

The "pit's mouth," or rather "*dhand*-shore" value lies apparently between Re. 1 and Re. 1-14 at the present time.

The right to excavate *chaniho* is put up to auction every year in Nawabshah. Last year a bid of over Rs. 7,000 was received, the average total production in the last two preceding seasons having been 7,495 maunds. Re. 1 per maund is therefore a minimum sale-price at which the lessee could normally sell without loss.

¹ Letter No. 3039 Rev. Dept., dated 15th October 1917, from A. W. Mackie, Esq., I.C.S., Collector of Nawabshah District, to the Commissioner in Sind.

Since my visit to Sind took place in the cold weather, I did not witness any *dhand* being worked. I have however made the following notes—

Methods of extrao-
tion.

The season for collecting *chaniho* is from April to October. *Chaniho* is removed in May or June, when the *dhands* owing to evaporation are at their driest. If the rains, which usually fall in July, are abundant, no more *chaniho* can be obtained that season, since the bitterns do not become sufficiently concentrated. But if the rains are scanty, the *dhands* again become sufficiently concentrated to yield *chaniho* in September or October, and thus two annual crops are obtained.

In order to prevent undue dilution of the *dhands* by the rain or by the *sim* water, *bands* (or low mud embankments) about one foot in width, are constructed, so as to divide the *dhand* into compartments. *Bands* are constructed parallel with the shore, and about 10 yards out; the water between the shore and the *band* may become dilute, but that inside the *band* continues to evaporate. Besides the *bands* parallel with the shore, others subdivide the enclosure thus made into smaller compartments. Plate 10 (Photograph of Ganjawari) shows these *bands*. They are only to be found in certain *dhands* which have a slight excess of water. The *chaniho* forms a thick crust when the *dhand* or a compartment is sufficiently dried, and is cut out with pick and spade. It is now carried to the shore in baskets, and stacked in conical stacks from 4 to 5 feet in height (see Plate 11, View of Pakhyaro *dhand*). These stacks are then covered with grass to protect the *chaniho* from the rain; the stacks now look very much like the ordinary haystack with which we are familiar.

The purer *chaniho* forms crusts in the shallower parts of the alkaline *dhands* or around the margins, while the salt and sulphate remain in the bittern, which occupies a circumscribed space in the centre or deeper portion of the *dhand*. But others of the *dhands* dry completely, and when this happens the *chaniho* is less pure. However purer *chaniho* usually marks the outer zone of retreat of the drying-up bittern, and the impurer residue will be found in the middle. The intelligent workman may reject this,—or may not. I have elsewhere recorded that the workman seems to be quite as well satisfied with sulphate of soda as with trona, and stacks both.

The price of soda-ash has risen from Rs. 5-4 per cwt. in 1912 to Rs. 5-12 and Rs. 6-4 in the present time.

The imports of soda-ash and soda-crystal into India during the last four years were :—

	Tons.
1914-15	22,627
1915-16	27,639
1916-17	18,376
1917-18	35,014

Bengal consumes more than three-fourths of this supply. Without accurate measurements of depth and area of each *dhand*, it is not possible to form any estimate of the amount of soda available as trona in the large unworked *dhands*. Furthermore it would be necessary to carry out experiments in the fractional crystallisation of trona from solutions of similar composition to that of the *dhands*, before any estimate could be made. It is obvious however that many of the larger *dhands* contain very large quantities of soda; probably the two largest—Pur Chandar and Khariri—contain each up to 25,000 tons. There are other large alkaline *dhands*, the waters of which I have not analysed, *e.g.*, Bitrawaro, Bitriwari, Nichora, Pharanwari, Ram Rabu, Khabbarwari-Lambreji, Kinri, Lun Khan Ulan, all of a good size, besides possibly some which I have not heard of. To this unknown quantity has to be added the trona produced annually from the producing *dhands*, the figures for which have been given above.

Besides the quantity of trona actually in the *dhands*, it must not be forgotten that a small amount is brought in annually by the *sim* or percolating water.

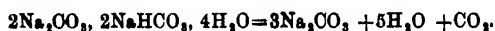
As a general conclusion, it may be admitted that there is a possibility of developing the trona of Sind provided that—

- (1) a market can be found for natural soda, which seems always to be more impure and more discoloured than artificial soda produced from salt, and
- (2) that the trona can be recovered and calcined cheaply.

The development of the Sind soda will, in my opinion, depend mainly upon these two points.

According to Martin, Smith, and Milsom's Manual,¹ 14½ tons of coal are required to calcine every 100 tons of soda-ash produced from bicarbonate of soda.

Now 100 parts of trona correspond to 70.3 parts of soda-ash, according to the equation:—



452 :

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that is 38.7 maunds of trona=27.2 maunds, or 1 ton, of soda-ash.

That is for 3,870 maunds of trona or 100 tons of soda-ash, about 14.5 tons of coal are required, or 394.4 maunds, assuming that a nearly similar quantity is required for trona as for bicarbonate.

The cost of recovery of the trona from the bitterns is impossible to estimate. I may mention however that at the Salt-Gardens at Maurypur near Karachi, the recovery of salt from sea-water costs in the present time (1918-19) of high prices, five annas per maund according to information received from Mr. Thurley. The cost of recovery of trona is of course a very different matter, but in general principle the operations are similar, consisting as they do of the concentration by solar evaporation of dilute solutions.

The price of soda-ash produced artificially is Rs. 5-14 per cwt. or about Rs. 4-5 per maund. The soda-ash produced from natural trona would be less pure than the artificial article; I do not think one could aim at a purity of much over 90 per cent. In consequence it could not command so high a price. Nevertheless even if it fetched only Rs. 3-8 per maund, it seems possible that there might be a final margin of profit sufficient to make it worth while to develop the industry.

Whatever be the future of the soda industry of Sind, it would

Conclusion. certainly be advisable to work at least the existing *dhands* in a scientific manner, having regard to the principles of chemistry, and applying a knowledge of the fractional crystallisation of "triple" waters to practical purposes in the process of recovery of the trona.

¹ 'The Salt and Alkali Industry', by G. Martin, S. Smith, and F. Milsom, 1916, p. 71.

In the foregoing account of the *Chaniho*-Industry of Sind,—a somewhat cursive sketch, the result of rapid observations carried out in a period of two months,—I have not thought it necessary to discuss methods of recovery of trona, which must be left to the ingenuity of whatever company cares to take up the proposition. The report is far from being exhaustive, and future observers will doubtless find much to add and something to correct. None of the samples collected were average samples; they were simply specimens rapidly collected. The figures given, the analyses as a whole, are therefore only approximations, and are bound to be to a certain extent inaccurate. The sizes and depths of the *dhand*s are merely guessed.

APPENDIX.

RATES FOR TRANSPORT OF SODA-ASH FROM PITHORO AND KHADRO TO KARACHI.

* * * * *

The following rates for transport by goods train from Pithoro and from Khadro to Karachi were communicated to me in 1919 by the kindness of the Eastern Bengal Railway.

Soda-ash (alkali) from Pithoro to Karachi, *via* Haidarabad :—

					At Owner's Risk per maund.	At Railway Risk per maund.
					Rs. A. P.	Rs. A. P.
Jodhpur-Bikaner Railway	.	.	.	.	0 2 3	0 3 2
North Western Railway	.	.	.	.	0 3 4	0 4 11
Surcharge	.	.	.	.	0 0 2	0 0 2
TOTAL					0 5 9	0 8 3

Soda-ash (alkali) from Khadro to Karachi, *viâ* Mirpur Khas and Haidarabad :—

	At Owner's Risk per maund.	At Railway Risk per maund.
	Rs. A. P.	Rs. A. P.
Jodhpur-Bikaner Railway	0 3 8	0 5 1
North Western Railway	0 3 4	0 4 11
Surcharge	0 0 2	0 0 2
TOTAL	0 7 2	0 10 2

The above rates are subject to confirmation by the railways concerned.

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G de P. Colter, Photo

GANJAWARI DHAND, KHAIRPUR STATE.

A typical chaniho producing dhand showing dams dividing the dhand crosswise and lengthwise into compartments.
Chaniho is forming at the south end (left hand side)

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